R/V POSEIDON

Cruises
252/253
(1999)

Institute for Geosciences
Departments of Geophysics and Geology/Palaeontology

2000

Contents

Preface

The cruises 252 and 253 of RV "Poseidon" were performed for a common project on the investigation of hydrothermal activities in the area of the Tjoernes-Fracture-Zone north of Iceland. The main objectives were focussed on the investigation of the structure and morphology of hydrothermal vents. Multichannel reflection seismic investigations were performed during the first leg as a pre-site survey for the subsurface structures beneath recent hydrothermal vents and the seismic characterisation of the seafloor, whereas the second leg was dedicated to the investigation of the morphology in the vent areas using cores and the research submersible "JAGO". The main strategy of the combination of a geophysical and a geological/ geochemical cruise leg was to illustrate the relationships between heat sources in the subsurface and the formation of vent fields at the sea floor in order to get a more comprehensive understanding of the dynamic processes of fluid circulation and the formation of the uppermost sediments.

Two reflection seismic sections show clearly the position of a magma chamber beneath a vent field thus indicating the energy source which is driving the thermal fluid circulation in the overlying sediments that showed quite clearly when cores were heaved on board and they were still boiling. The combined interpretation of the data shows a clear correlation between phase reversals in seismic response and high gas accumulations as well as anhydrite in cores and expected seismic reflections coefficients of this sampled material. Thus combination of geophysical and geological methods have prooven that reflection seismic investigations can reveal sea floor characterisics and their spatial distributions after calibration by groundtruthing in a very effective way. For future cruises a complete bathymetric survey should be included in the research programme as many subsurface features are imaged in the bottom morphology of the sea floor.

Fr. Theilen
J. Scholten
(January, 2000)

Cruise Report
RV Poseidon **252**

Carsten Riedel
Friedrich Theilen

Cruise Report

R.V. Poseidon Cruise No. **252**

Dates: **26/06/99 - 07/07/99**

Subject of Research: **Marine Seismics (Geophysics)**

Institute: **Institut für Geowissenschaften**
Abteilung Geophysik
Christian-Albrechts-Universität Kiel
Otto-Hahn-Platz 1
24118 Kiel

Chief Scientist: **Dr. Fr. Theilen**

Number of Scientists: **10**

Project: **„Hydrothermale Zirkulation am Kolbeinsey-Rücken", Project of BMBF No. 03G0541 A**

Contents:

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1. Crew, list and affiliation

Chief Scientist	Dr Friedrich Theilen	IfG Kiel, Geophys.
Scientists	Dr Mark Schmidt Dipl. Geophys. Carsten Riedel Dipl. Geophys. Christian Müller Anne Broser Sascha Bussat Simone Kugler Petra Liersch Cord Papenberg	IfG Kiel, Geology IfG Kiel, Geophys. IfG Kiel, Geophys. IfG Kiel, Geophys. IfG Kiel, Geophys. IfG Kiel, Geophys. IfG Kiel, Geophys. IfG Kiel, Geophys.
Technician (Compressor)	Iain Miller	Exploration Electronics

IfG:Institut für Geowissenschaften

2. Research program

Survey area of Cruise 259 was the southern segment of Kolbeinsey Ridge that is heavily deformed by the crossing Tjörnes Fracture Zone (TFZ). The area was already examined by submersible and gravity cores during Poseidon Cruise 229 a. The primary aim was to detect further evidence for hydrothermal activity, deliver seismic attributes of the sea bottom, to map adjacent fault systems and sedimentation patterns, that are essential for modelling of the hydrothermal cells of the slow-spreading mid ocean ridge. Analysis of the data will also enable us to deepen the AVO research of marine sediments and to image deep reflectors and thus hopefully to gather evidence for separating Kolbeinsey Ridge to the north of the survey area and the Iceland Plume to the south of the area.

3. Report of cruise with technical details

26/06/99 (*Saturday*): The compressor is moved from port side to midship.

27/06/99 (*Sunday*): After a guided debark from Reykjavík at 08.00h , the equipment is prepared, i.e the protection is taken from the streamer, the carrier buoys are filled with pressurized air and the airgun pressure and trigger cables are equipped at port side. Magnetic valves and airguns get checked. At 10.00h cables and airguns are ready for float.

28/06/99 (*Monday*): At 15:00h RV Poseidon reaches the limits of the survey area. The streamer is rolled out from midship, at port side an airgun array (1x0.87 l and 1x0.33l) is deployed into the sea water of the North Atlantic Ocean. Floating stable everything is ready for acquisition. The 0.87 l gun begins shooting every 10 s. Line 1 is registered.

29/06/99 (Tuesday): The 0.87 l airgun begins shooting Line 2 while the original trigger impulse is lagging behind and is very unstable. A pressure drop to 100 bar forces a change to even worse conditions, so pressure is increased to 120 bar again and finally the gun shoots regularly, so that line 2 to line 9 are recorded.

30/06/99 (*Wednesday*): Line 10 to 12 are acquired without any problem the registration of Line 13 starts. The daily compressor check interrupts acquisition for a short period of 6 minutes. Until acquisition of 17 starts, no more interruption takes place. The trigger box, suddenly, stops. No reason for the break is found, but an hour later everything is fine again and recording continues.

01/07/99 (*Thursday*): With the trigger box working again acquisition of Line 17 goes on using the second 0.65l gun up to 6:15h. Lines 18, 19 and 20 are registered. Line 21 has to be cancelled at 16:42h because of fishery fleets crossing over. Line 22 and 23 are again acquired without any problem. Line 24 is started.

02/07/99 (*Friday*): Line 24 is over at 00:12h. Lines 25, 26 and 27 are recorded. After a working time of 75 hours the airguns are hauled up from the sea water. They deserve a pause and are exchanged by a 0.87l and a 0.33l airgun. In the mean time the streamer that got a small damage on PO 251 is checked. The cables of the airgun reveal problems and are protected by a new layer of textile tape. The pressure connector of the 0.87l airgun is exchanged, as well, for security reasons. The array is connected to the prepared 2 m buoys and at 13:25h airgun array and streamer are set afloat again. The exchanged airguns look well even after 75 hours. Only some condensed water was found in their chambers. Even one airgun that had to be repaired on the Canary Islands is working well, so Line 28 and Line 29 do not face us with problems.

03/07/99 (*Saturday*): On Lines 30 and 31 no failure is perceived. Line 32 imposes the irregular shot problem again at 06:35h. We switch to the 0.33l airgun. Everything works well up to the end of the Line. As acquisition starts on Line 33, the airguns do only work in very irregular patterns. Trigger box check and pause, trigger impulse reduction to 10 sec and pressure regulation do not change the situation for better. So at 10:15h the array is taken out of the sea water again. The rope fitted to keep the airgun cables from tearing is torn itself. The observation that the cable was somehow shaved from something metallic is confirmed. The whole cable drum of the array has to be exchanged. At 11:30h the new array is ready with 2 0.65l guns und 2 m distance carrier buoys. Shortly afterwats the array is deployed. A 0.65l gun is shooting every 5 seconds and Line 33 can be finished off. Registering Line 34 starts.

04/07/99 (*Sunday)*: Line 34, 35 and 26 have been registered with no negative encounter. The array is brought aboard, the streamer is rolled onto the drum. The streamer is blocked with its plastic and wood protection again. The airgun strings and arrays are deconstructed.

05/07/99 (*Monday*): During the voyage back to Reykjavík the instruments are packed into the appropriate boxes again. The rooms are cleaned up.

06/07/99 (*Tuesday*): At 09:00 the RV Poseidon is guided into Reykjavík Gamla Höfn. The whole load is taken from board by crane into a container. Some single boxes are packed as single goods.

4. Scientific report and first results

The main target of the cruise were the vent-fields of the southernmost part of the Kolbeinsey Ridge that is heavily transformed by the crossing Tjörnes Fracture Zone (TFZ). Along the Grímsey Lineament two such fields were discovered by the Jago submersible during cruise PO 229/2, the East Grímsey vent-field and the Kolbeinsey vent-field (Stoffers et al., 1997, Devey et al. 1997). The purpose of seismic research in this area was to map the adjacent fault systems and the sedimentary structure beneath the anhydrite enriched systems, to supply the geochemical data with a fundamental research of character, bedding and distortion of the underlying rock. During Poseidon cruise 146/3 in 1988 the northern environment was already examined by seismics and negative amplitude trends were found locally that gave hints to gas reservoir or bubbles directly at the water bottom (Neben, 1992). In light of the Jago research this is understood as the output of the vent-fields. All in all, 36 reflection lines were registered north of the island of Grímsey and south of Kolbeinsey („Kolbeinn's Isle") (see Fig. 1) first to characterize known vent-fields and further more to detect new ones. The data was checked onboard for similar features to supply the following PO 253 journey with coordinates of those apparent vent-fields identified by seismic. A recheck was established by the onboard echo-sounder and fish-finder of RV Poseidon.

Thus, the strategy was to detect typical features of known vent-fields and our first target was the East-Grímsey vent-field (Stoffers et al., 1997). Whereas a first seismic reflection line (Line 6) did not show satisfactory results a sequentially registered star of seismic lines centering the vent-field of an estimated area of 300 m x 1000 m showed the typical negative amplitude trend (Fig. 2). Mapping of these trends revealed a nearly undistorted elliptically shaped gas bubble above the field (Fig.3). Closer inspection of the amplitudes (Fig.4), however, shows an ambiguous detail trend. Although the phase rotation is clearly visible observing the maximum amplitudes, there is a positive precursor wavelet on the negative trends of the apparent gas bubbles, as well, i.e phase rotation is not 90°. More information will be given when an AVO analysis of the data has been conducted.

The second known vent-field, Kolbeinsey Hydrothermal Field, was directly hit by our first approach and showed the typical dotted, bubble-like structures of vent-fields on the echo-sounder, which can only be caused by the difference between the acoustic qualities of normal sea water and those of the brine above the hydrothermal area. A negative amplitude trend similar to the one of East-Grímsey vent-field was discovered, but detailed AVO analysis, again, belongs to a later phase of processing.

Detecting vent-fields by seismic reflection

The first glimpse at 2 known vent-fields opened the view to similar structures.

- Vent-fields at Kolbeinsey Ridge are apparently always imaged as topographical highs.

- It is clearly visible from comparison, that directly at the vent-fields multiples are less in amplitude, i.e. they have a lower reflectivity than their surroundings.

- They are never imaged by their real bathymetry but by many diffraction hyberbola hinting at their compound, rough structure.

- The negative amplitude trends are bound to the flanks of such compound structures, where often interfingering of seismic strata can be examined, which are unambiguous proof for fault structures.

- Often the topography high is surrounded by a highly active fault system of two normal faults inclined to the center of the vent-field, that is imaged as a topographic undulation and a fault.

Taking these information into account and further information from seismology and bathymetry in this area (Rögnvaldsson et al., 1998) RV Poseidon headed towards new vent-fields. We connected the northern and southern vent-fields by reflection Line 17, which allowed for 3 more vent-field positions (see Table 1).

Vent-field	N	E
Seismic A	66°41,00	17°51,00
Seismic B	66°43,50	17°59,00
Kolbeinsey Southern Field (KSF)	66°58,00	18°43,00

Table 1: Postulated vent-field locations from reflection seismology.

The structure of vent-fields

A very strong candidate, Kolbeinsey Southern Field (KSF from Table 1), was crossed again during acquisition of Line 28 (Fig. 5, see also Appendix). All features are observed as above (with the exception of the normal faults, that occur only to the north of the field). Additionally, this was the only location where 2 deep reflectors (ca. 1.5 s and 2.1 s) could be illuminated, which is why this area (Common Depth Point (CDP) 1760) was chosen for a velocity analysis (Table 2, Fig. 6). These two reflectors were expected to be top and bottom of a magmatic intrusion and a test stack at CDP 1760 supports this thesis.

Time (in ms)	RMS-Velocity (Stack)	Interval Velocity (after Dix)
0	1497 m/s	1497 m/s
524	1507 m/s	1507 m/s
676	1614 m/s	1938 m/s
835	1863 m/s	4299 m/s
1390	3076 m/s	4654 m/s
1643	3368 m/s	3322 m/s
2054	3445 m/s	

Table 2: shows the results of a velocity analysis of CDP 1760, the interval velocities between 0 and 676 ms hint to sedimentary or clastic structures, whereas below 835 ms velocities of basalt are hit. Below the structure at 1643 ms the velocity decreases, however, the level could as well be chosen for interval velocities from 2700 m/s to 3800 m/s and would still fit the reflector hyperbola.

The deep reflectors seen on Fig.7 could be extrapolated much better after high-pass wavelet transform filtering eliminating all frequencies up to 62,5 Hz. A band-pass does not deliver equally good results. An airgun bubble elimination by predictive deconvolution is not so easy to develop as to show it in this report and has to be postponed to a later phase of processing. Structurally and from its seismic properties (see Table 2), the area discovered on Line 28 resembles closely a vent-field with a shallow magmatic intrusion, that appears to be the heating of the hydrothermal system. The magmatic intrusion was already detected on Line KR 18 during RV Poseidon cruise 146/3 in 1988 (Neben, 1992). At that time it was suggested to be non-steady state. That might well be during a geologically important time scale. During the last 4 years it might have changed its structure, but it did not shift its position.

Evidence for scarce sedimentation

Sedimentation occurs rarely in all of the survey area according to the reflection lines acquired, i.e. thick beds are not observed. A maximum signal frequency of about 250 Hz can only resolve wavelengths of 8 m, i.e. gravity cores from Poseidon cruise 175 (Lakschewitz et al., 1990) of the upper 5 m may reveal fresh sedimentation even on the tops of ridges, this is not eaily accessed by seismic reflection surveys. A maximum sedimentation thickness of about 100 m in the whole region is again oberved on Line 28. Strong multiples throughout the whole registration suggest high reflectivities, thus it is more likely that most of the imaged sea bottom is made of basalt than sediments. Many diffraction hyberbolae are also typical for basalt and give another evidence for this hypothesis.

Seismic attributes of the sea bottom reflection

Beneath some of the structural highs, multiples disappear. On first glimpse we propose, that most of these areas (Fig. 8), if not coincident with negative amplitude trends, show old anhydrite plateaus, that were originally built up by vent-fields that have now moved to different places, because magmatic intrusions, as the sill above, have cooled down substantially or are frozen through. These anhydrite ridges can be distinguished from other ridges by their scattering effectivity. Even the airgun bubble component is not imaged as strong as the signal in the ridges, i.e. they are not equivalent in reflectivity to basalt in the same frequency range (Fig. 9).

Seismic characterization from vent-fields seems to be possible north of Iceland. But, as the filtering shows, new experiments should be carried out with a higher amplitude high frequency (>50 Hz) component, i.e. an array of small airguns or water-guns. Improvement of data quality will arise from high-pass filtering, but the characterization of anhydrite structural highs above implies, that the low-frequency component may be essential in detecting the hydrothermal areas.

5. Scientific equipment

The seismic survey was shot with:
- a 600 m streamer with 24 hydrophone groups spaced 25 m and a ship offset of 230 m.
- 2 x 0.33 l airguns
- 2 x 0.65 l airguns
- 2 x 0.87 l airguns
- a Geometrics Marine Controller II registration unit
- GPS-NAVigaton from RV Poseidon
- a Pentium PC-Network of 4 PCs running LINUX

6. Appendix of charts, list of reflection line coordinates

Line No.	Start of Line (N)	Start of Line (W)	End of Line (N)	End of Line (W)
1	66°24,00'N	18°58,00'W	66°47,50'N	17°47,00'W
2	66°46,00'N	17°43,50'W	66°39,75'N	18°02,75'W
3	66°38,00'N	17°59,00'W	66°44,25'N	17°40,50'W
4	66°42,75'N	17°37,00'W	66°36,50'N	17°56,00'W
5	66°34,75'N	17°53,00'W	66°41,25'N	17°33,50'W
6	66°39,75'N	17°30,50'W	66°33,50'N	17°49,50'W
7	66°32,00'N	17°47,00'W	66°38,25'N	17°27,50'W
8	66°36,75'N	17°24,50'W	66°30,50'N	17°43,50'W
9	66°29,50'N	17°42,00'W	66°36,00'N	17°23,00'W
10	66°35,25'N	17°21,00'W	66°24,00'N	17°55,00'W
11	66°22,25'N	17°51,00'W	66°30,75'N	17°27,00'W
12	66°30,75'N	17°27,00'W	66°46,50'N	18°00,00'W
13	66°46,50'N	18°00,00'W	67°05,50'N	18°14,00'W
14	67°05,50'N	18°14,00'W	67°05,50'N	18°49,00'W
15	67°08,00'N	18°49,00'W	67°04,00'N	18°38,75'W
16	67°07,00'N	18°38,75'W	67°00,25'N	18°56,00'W
17	67°02,00'N	18°56,00'W	66°35,00'N	17°33,00'W
18	66°36,40'N	17°26,50'W	66°36,40'N	17°51,00'W
19	66°38,25'N	17°50,50'W	66°34,50'N	17°28,00'W
20	66°33,00'N	17°30,50'W	66°39,75'N	17°48,00'W
21	66°41,25'N	17°44,50'W	66°32,00'N	17°35,00'W
22	66°31,50'N	17°39,25'W	66°41,50'N	17°39,25'W
23	66°41,25'N	17°34,50'W	66°32,00'N	17°44,00'W
24	66°33,00'N	17°48,00'W	66°40,00'N	17°30,00'W
25	66°38,50'N	17°26,50'W	66°34,50'N	17°05,50'W
26	66°36,00'N	17°51,25'W	66°46,00'N	17°51,25'W
27	66°43,50'N	17°49,00'W	66°43,50'N	18°55,00'W
28	66°43,00'N	18°44,00'W	67°02,00'N	18°44,00'W
29	67°03,50'N	18°55,00'W	67°07,25'N	18°31,75'W
30	67°05,50'N	18°29,50'W	67°05,50'N	18°55,50'W
31	67°07,25'N	18°53,75'W	67°03,50'N	18°30,50'W
32	67°01,00'N	18°38,00'W	67°09,00'N	18°46,25'W
33	67°08,50'N	18°48,00'W	66°50,50'N	17°25,00'W
34	66°46,00'N	17°30,00'W	66°46,00'N	19°00,00'W
35	66°48,00'N	19°00,00'W	66°48,00'N	17°30,00'W
36	66°51,00'N	17°30,00'W	66°51,00'N	19°00,00'W

7. Acknowledgements

We like to thank captain and crew of the RV Poseidon for their cooperation and observation during cruise and charging of the cargo. We thank the BMBF for financing the project (03G0541-A). As well, we thank Anne Broser and Tanja Petersen for preparing some of the graphics displayed here.

8. References

Neben, S., 1992, Der Aufbau des südlichen Kolbeinsey Rückens aus reflexionsseismischen Messungen, Dissertation, Universität Kiel

Rögnvaldsson, S.T., Gudmundsson, A., Slunga, R., 1998, Seismotectonic analysis of the Tjörnes Fracture Zone, an active transform fault in north Iceland

Stoffers, P., Botz, R., Garbe-Schönberg, D., Hannington, M, Hauzel, B., Herzig, P., Hissmann, K., Huber, R., Kristjansson, J.K., Petursdottir, S.K., Schauer, J., Schmitt, M., Zimmerer, M., 1997, Cruise Report Poseidon 229 a „Kolbeinsey Ridge", Geologisch-Paläontologisches Institut Kiel

Figures

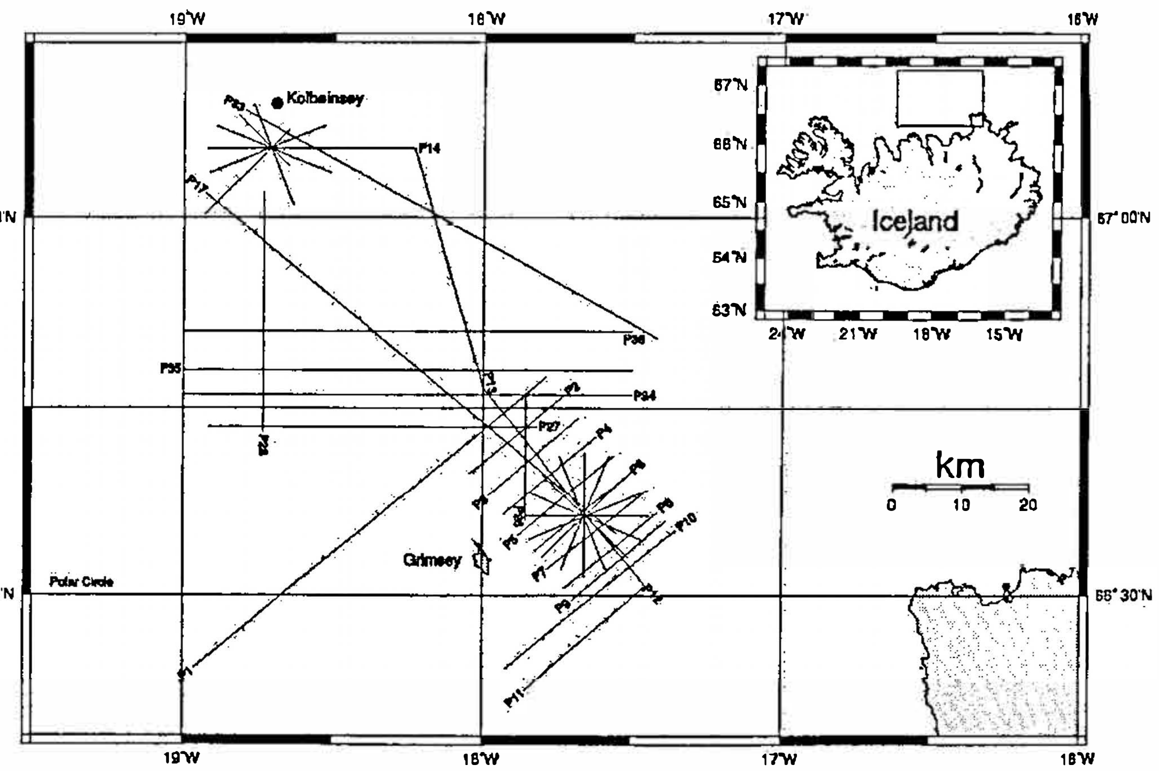


Figure 1: shows a map of the survey area and the acquired seismic reflection lines in between Kolbeinsey to the north and Grímsey to the south.

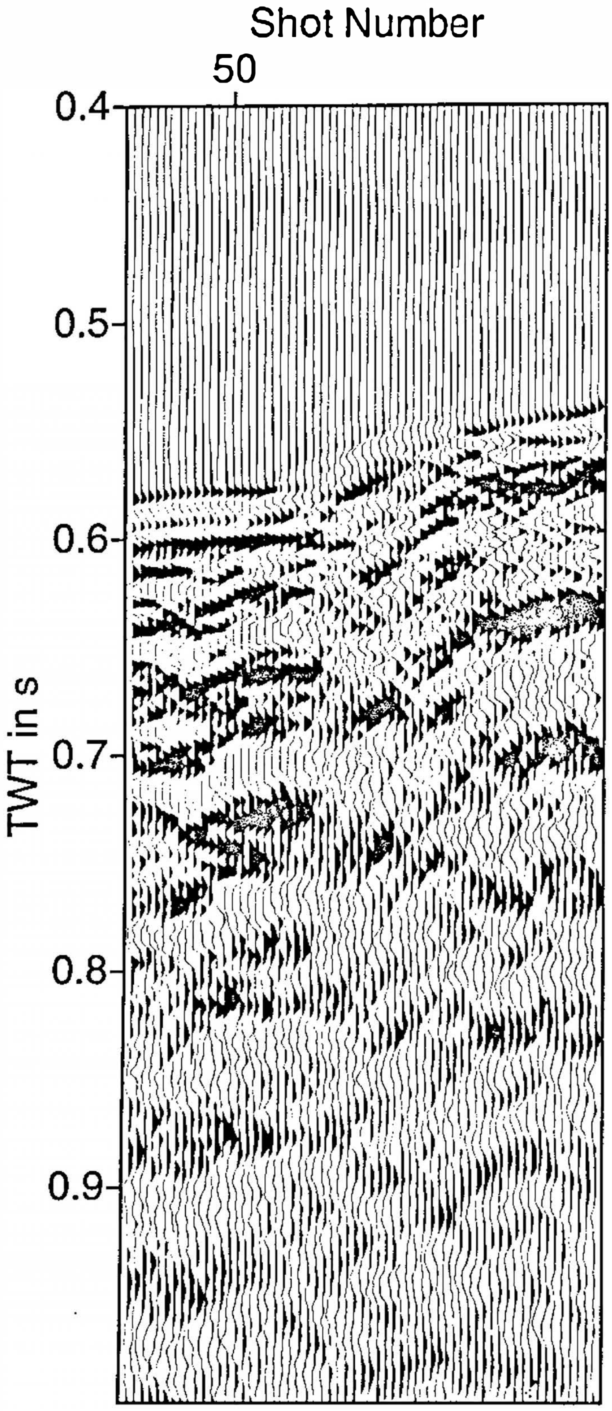


Figure 2: A negative amplitude trend of the first reflector, probably the gas plume, on Line 20.

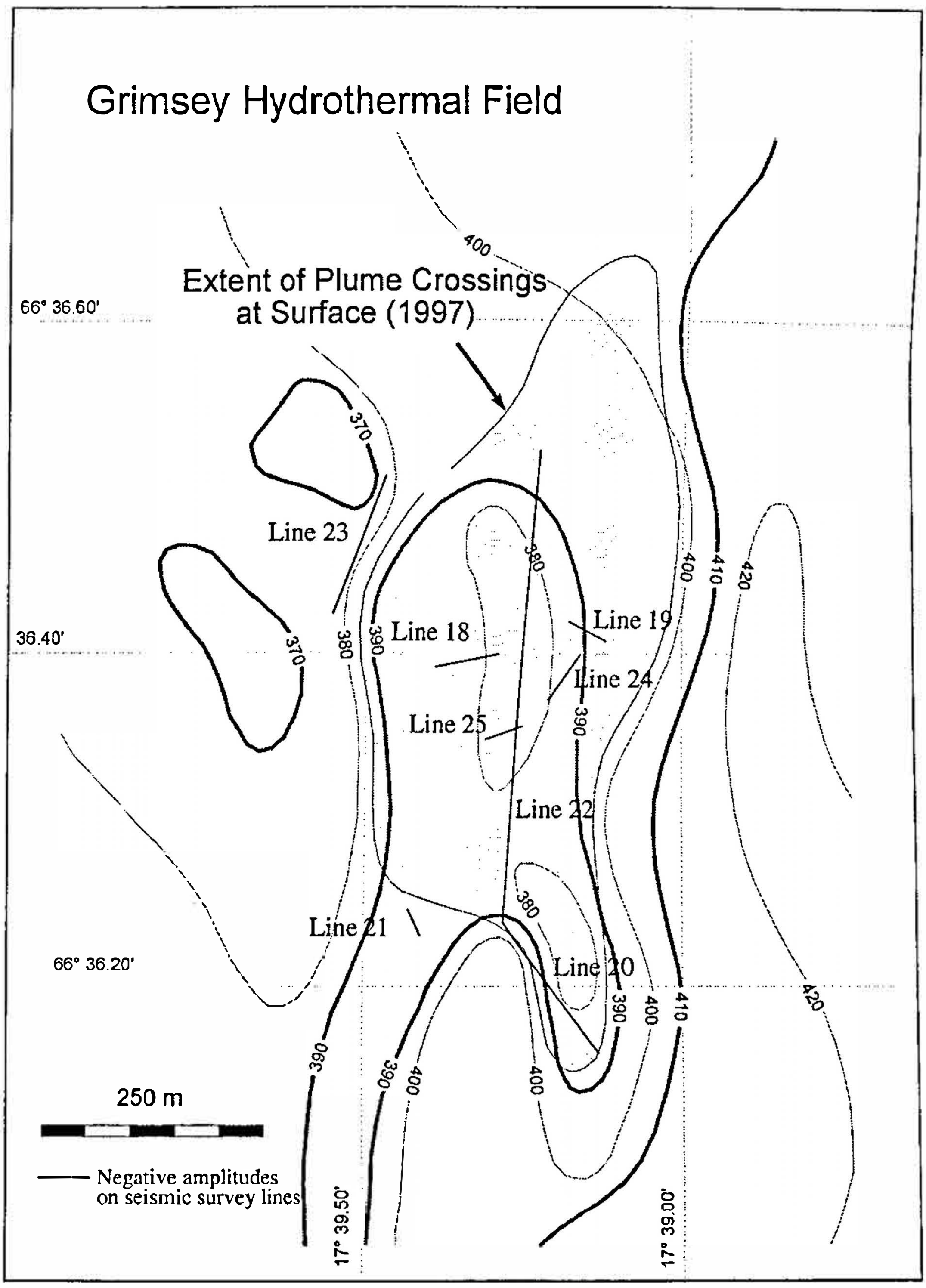


Figure 3: The extent of the gas plume from geologic measurement in comparison to the gas plume oberved by seismic amplitude phase rotation.

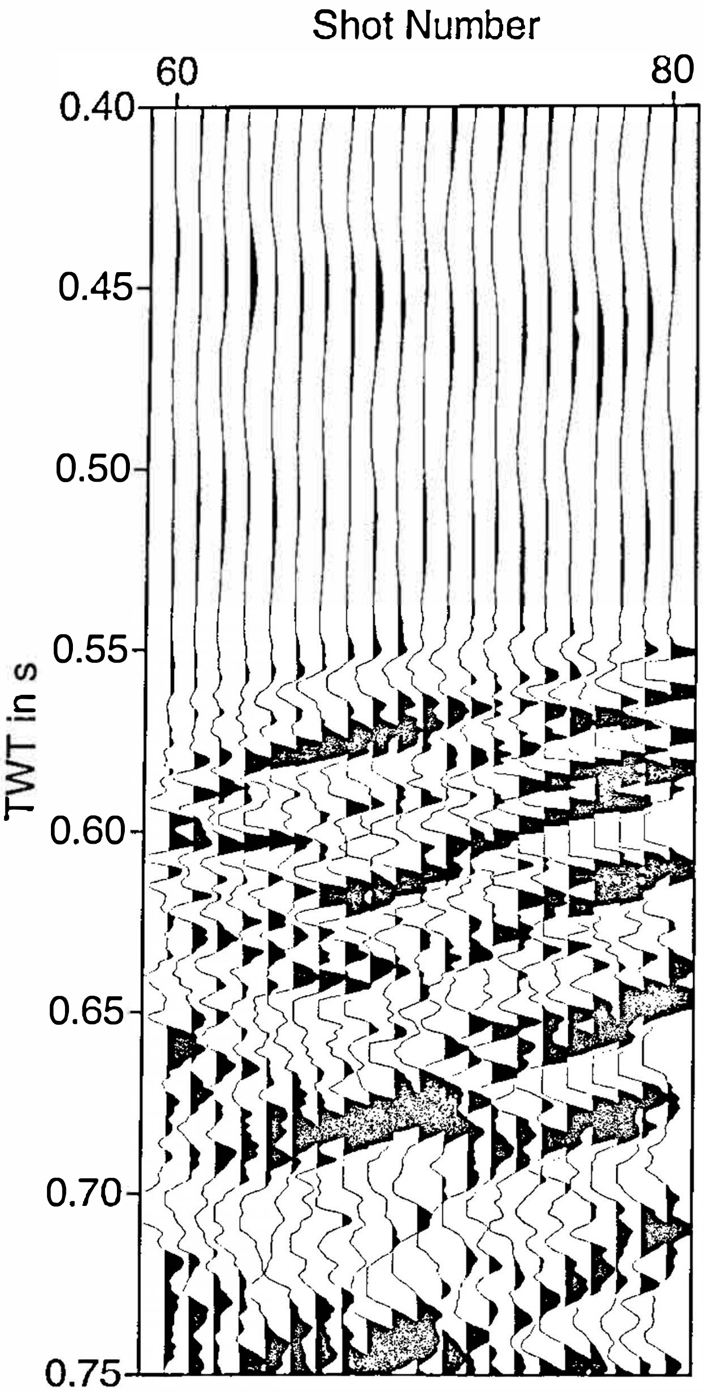


Figure 4: Zooming into the image of Figure 2, we see that the first reflector is not really a negative amplitude reflector, there is a precursor positive part before the actual negative maximum.

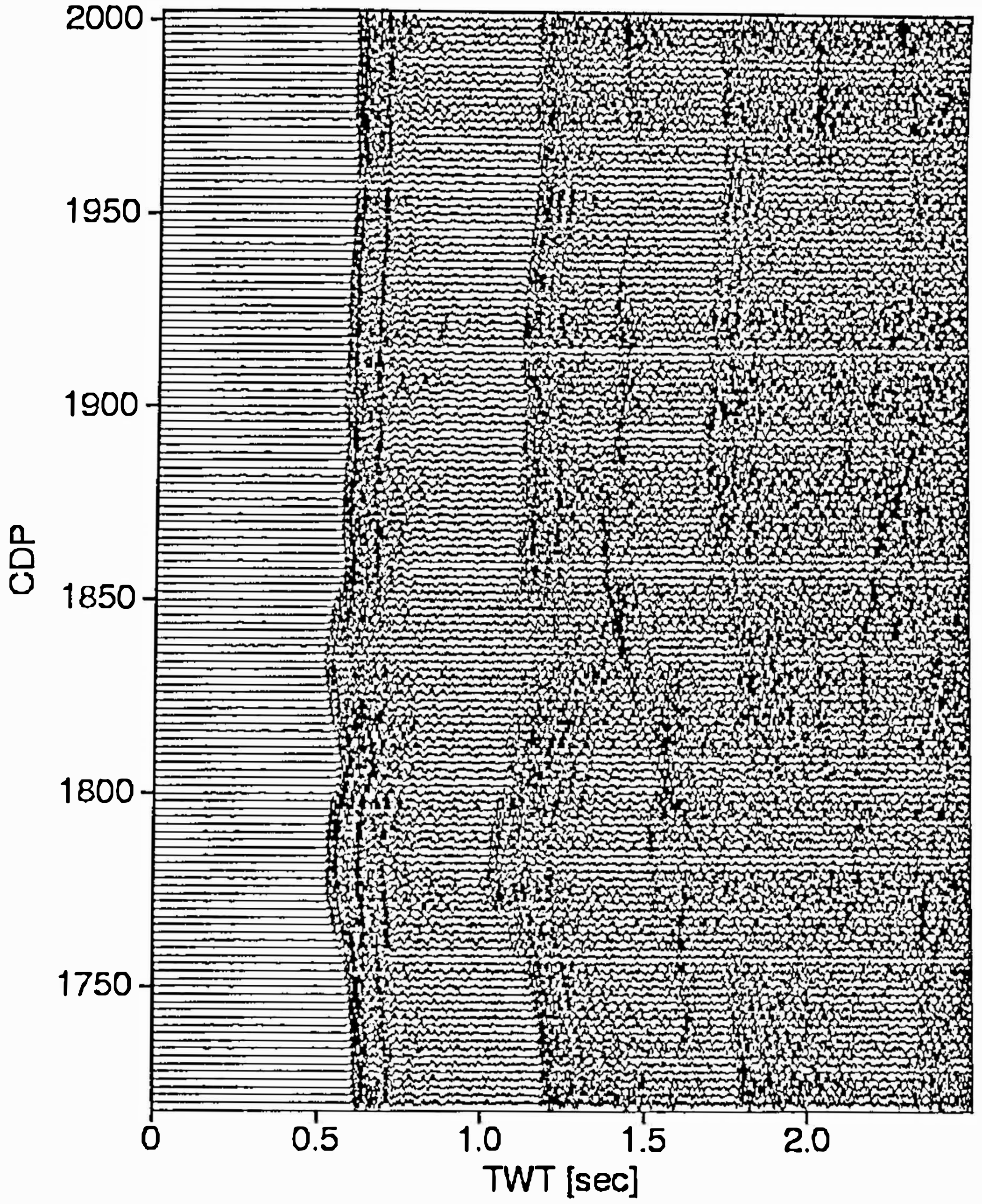


Figure 5: The high pass, trace normalized data from Line 28 (CDP 1700-2000) already shows some marked influence of the vent-field lithology , i.e. varying strength of multiples, and reveals its deep structure by a reflector at ca. 1.5 seconds two-way travel time (TWT).

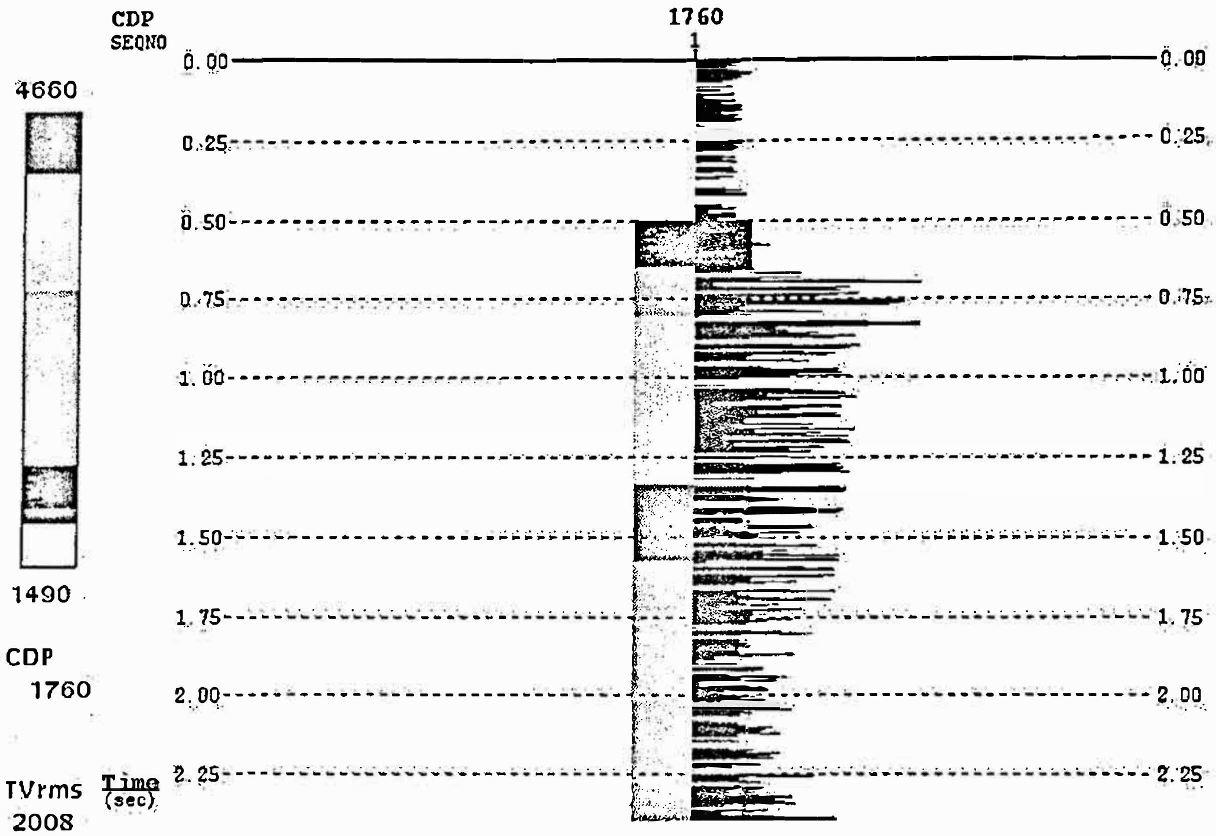


Figure 6: Velocity analysis by the professional seismic processing package FOCUS shows a decrease in velocity below the clearly visible deep reflector at 1.6 seconds. Here CDP 1760 is shown as an example. The legend shows the velocity color scale in m/s.

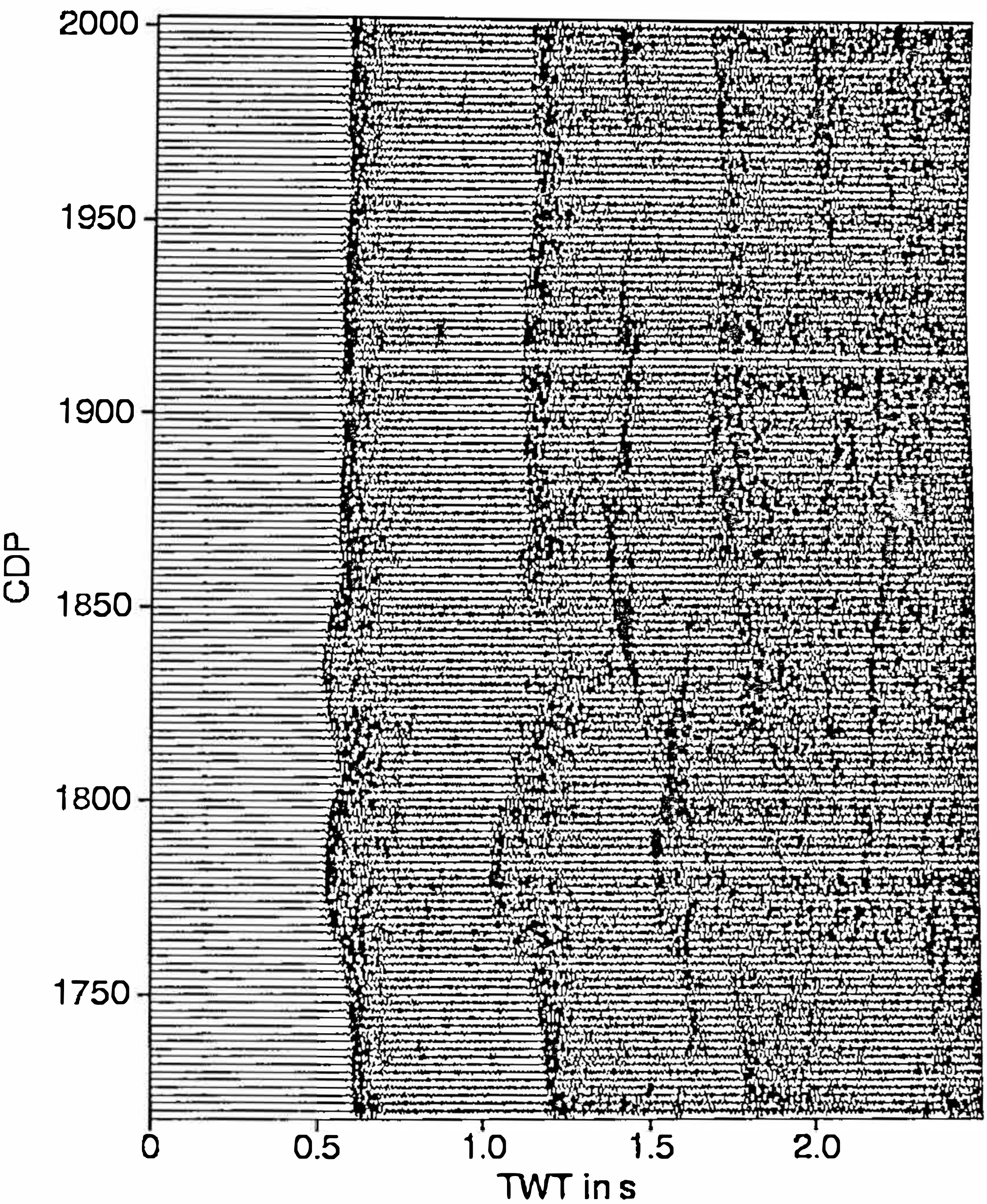
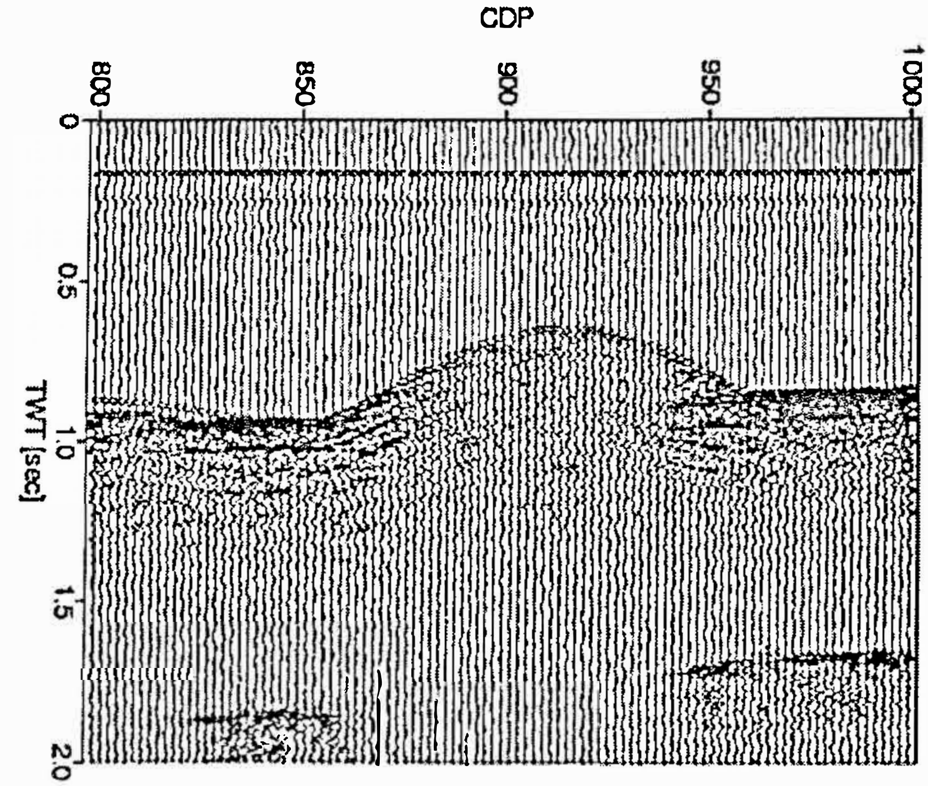
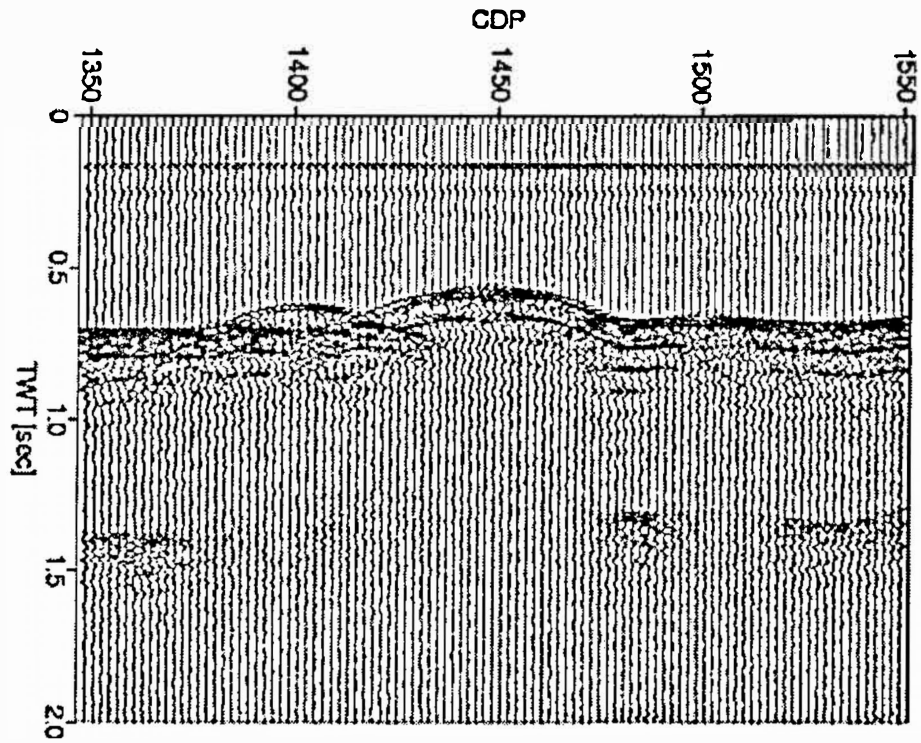


Figure 7: Interestingly enough, wavelet transform filtering by a Daubechies wavelet (20-coefficients) leads to a much better quality of the record, where other reflectors at around 0.75 and at 2.1 seconds gets visible, further more the bubble seems to eliminated.



a



b

Figure 8: The topographical highs on the seismic recordings differ in amplitude. The a) postulated anhydrite plateau is even less transparent to seismic waves than b) a basaltic ridge.

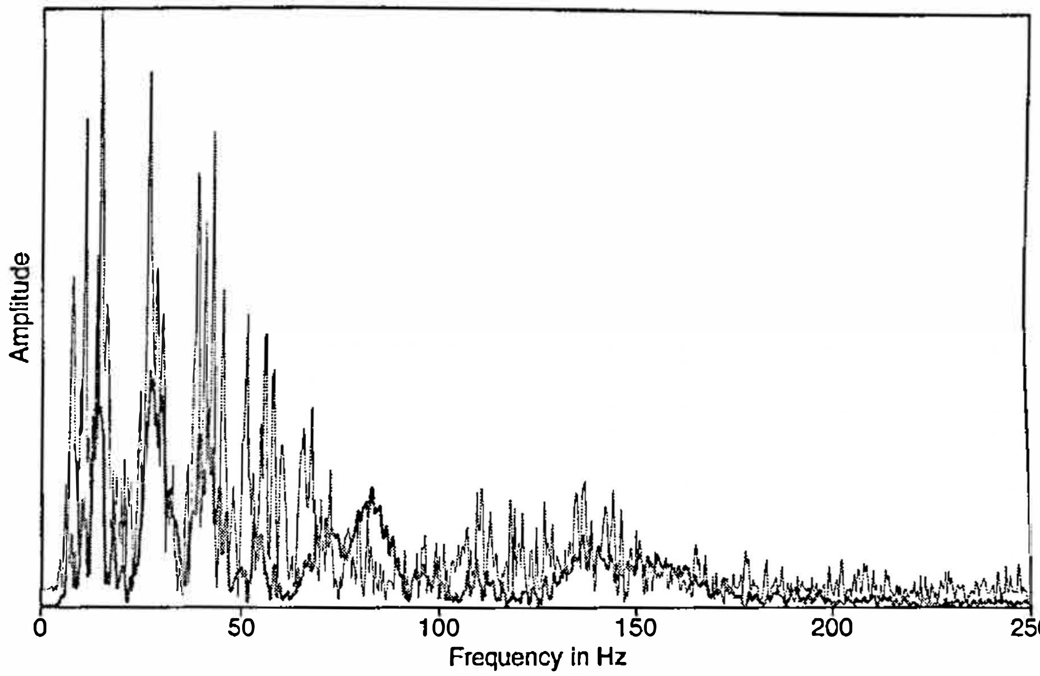


Figure 9: The frequency spectra in the range from 0 to 250 Hz show Anhydrite (thin black line) and basalt (thick grey line) reflection spectra in 2000 m offset. The Anhydrite spectrum is by far more noisy with strong spikes, suggesting stronger scattering effects. The biggest difference between the 2 lines is from about 50 Hz to 100 Hz.

Cruise Report

R.V. Poseidon. 253

Jan Scholten

R.V. Poseidon Cruise No. **253**

Dates: **07/07/99 - 22/07/99**

Subject of Research: **Marine Geosciences**

Institute: **Institut für Geowissenschaften**
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Project: **„Hydrothermalismus am Kolbeinsey-Rücken, Island“, Project of BMBF No.03G0524A**

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Scientific crew

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Summary

In-detail investigations of the Grimsey hydrothermal field as well as exploration of further hydrothermal active areas along the Tjoernes Fracture zone were the main objectives of Poseidon 253 cruise. On the basis of on-board interpretation of the seismic lines obtained during Poseidon cruise 252 and on the basis of recent seismic activities reported from the Tjoernes Fracture zone exploration of hydrothermal activity was conducted using various methods (echosounding systems, dredging, coring, diving using JAGO). In addition the distribution of methane in the water column was measured in these areas using Hydrobios water sampler (CTD). Hydrothermal activity could be confirmed by echosounding and methane anomalies in the Grimsey and Kolbeinsey hydrothermal vent areas (Botz et al., 1999).

Sampling and diving during Poseidon 253 focused on the Grimsey Hydrothermal Field. Several hydrothermal mounds with active venting chimneys on top were observed. All of the measured vent temperatures in about 400m depth ranged between 248° and 251°C with visible phase separation at the vent outlets. The up-to-three meters high chimneys consisted mainly of anhydride and talc. One piece of altered massive sulfide was also found. Bacteria traps were deployed, gas and venting fluids were sampled and markers at the outlets were dropped in order to identify and relocate the venting sites. Using the subpositioning system of JAGO it was possible to revisit the marked vent sites, and bacteria traps were re-collected after several days of their exposure to diffusive vent fluids.

On the flanks of the Grimsey graben and at locations were hydrothermal precipitates have previously been collected by fishermen, dredging was performed. The 13 dredge stations recovered only mudstones and altered basalts. At the Grimsey Vent Field and at its flanks sediments were sampled by means of 3m to 5m long gravity cores (17 stations). Intensely altered and baked mud with disseminated pyrite as well as thick sections of talc- and anhydrite-rich sediments were recovered. In some cores, as they hit the deck of the ship, boiling seawater trapped in the sediments was observed. Apart from one core, all temperatures of the sediments measured in the end of the core barrel were above 25°C (ambient seawater temperature was approximately 2,5°C). The "hot cores" map out an area of extremely high heatflow up to 1km from the main hydrothermal mounds and presumably delineate the extent of the subseafloor hydrothermal aquifer.

The first results of Poseidon cruise 253 suggest the Grimsey vent area to cover about 1km in length and 250m in width. According to the diving observations the Vent Field consist of several mounds which are composed of anhydrite and talc. On top of the mounds active venting chimneys occur surrounded by collapsed chimneys. Relatively low fluid venting and completely or nearly completely sealed hydrothermal mounds as well as extinct vents indicate a recent waning of hydrothermal activity at the southern ridge of the Grimsey Vent Field.

The Grimsey hydrothermal field provides the first opportunity to study an extensive subseafloor boiling system as well as fluid-sediment interaction in a shallow water setting. The mineral deposits and the hydrology of the system have important similarities to sites such as the Middle Valley, with potential for significant mineralization in the sediments at greater depth.

1. Research Objectives

The active neovolcanic zone on Iceland including the giant Krafla volcano is an area where the spreading axis of the Mid-Atlantic Ridge intersects the Iceland plateau. North of Iceland the spreading axis continues along the Kolbeinsey Ridge which is located about 75 km to the west (Fig. 1). The jump of the spreading axis between Iceland and the Kolbeinsey Ridge is facilitated by the Tjoernes Fracture Zone which consists of transform faults and associated small pull-apart basins.

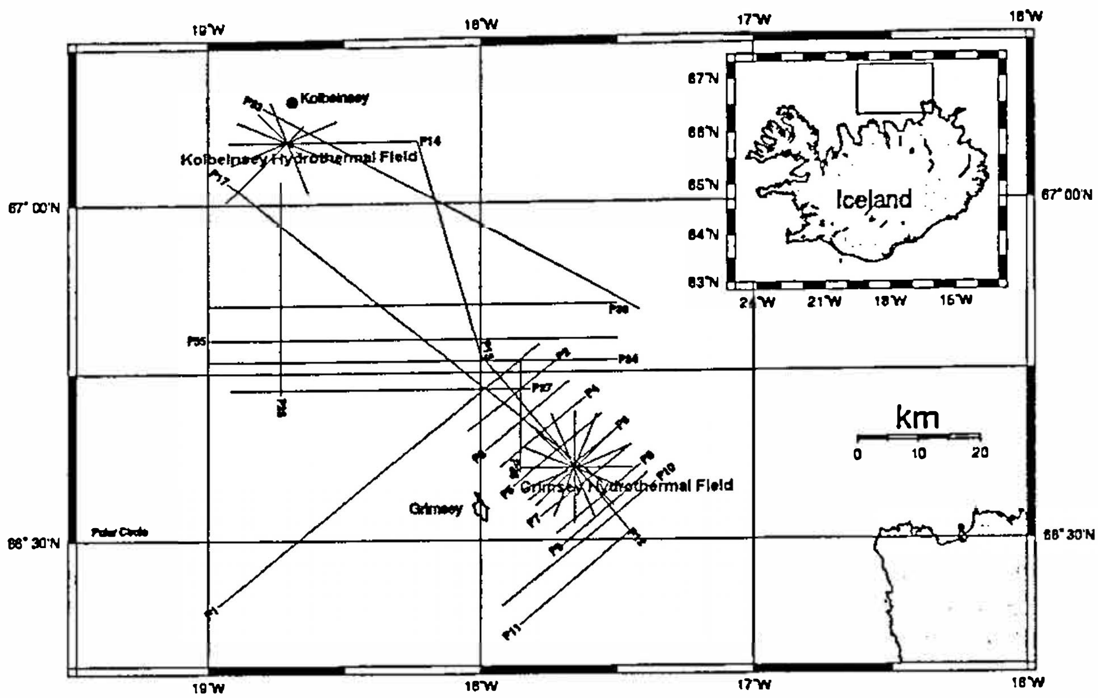
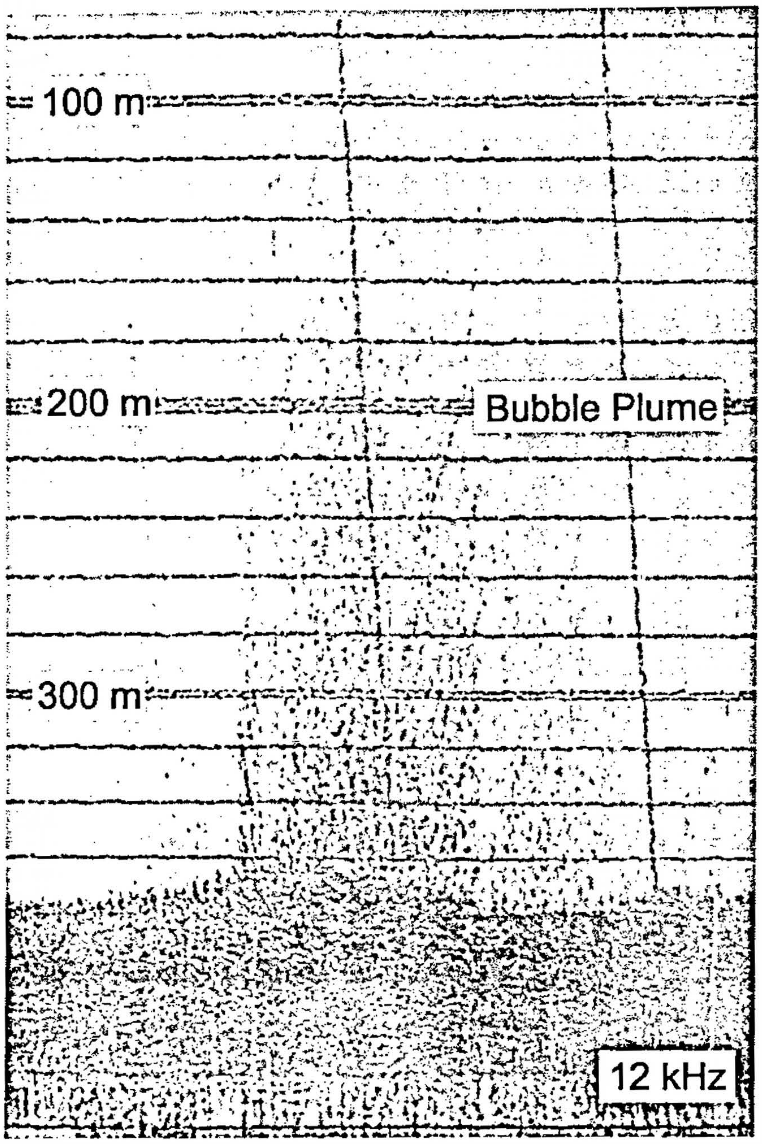


Fig. 1: Map of the survey area with seismic profiles

First reports of hydrothermal activity in this region came from a fishing trawler that observed gas bubbles at the sea surface at the Kolbeinsey ridge in 1974. Diving campaigns with GEO in 1988 and JAGO in 1997 (Stoffers et al., 1997) discovered active vents with temperatures up to 131°C in 100m to 110m water depths. Here, boiling and near-boiling fluids and gas bubbles emanated and discharged from fissures or crater-like pits. Hydrothermal precipitates consisted of orange-reddish mud or yellow-reddish iron-hydroxide staining on highly altered basalts. Further surveying along the Tjoernes Fracture Zone during POSEIDON cruise 229 (1997) discovered an active hydrothermal vent field mainly consisting of anhydrite chimneys and mounds with fluid temperatures up to 250°C in 400m water depth near Grimsey Island. This field is located in the Grimsey graben which is about 10km wide and 30-40km long and filled with glacial sediments from ice-fed rivers draining the north coast of Iceland.

During Poseidon 252 and 253 cruises in 1999 the region of the Tjoernes Fracture Zone was revisited by an international team of researchers from Germany, Iceland, and Canada. The scientific objectives include:

- High resolution geophysical profiling by multichannel seismic reflection in the southern Kolbeinsey Ridge area and the Tjoernes Fracture Zone
- Identification of hydrothermally active areas by on-board interpretation of seismic reflection records (sub-bottom fault systems, gas pockets and gas-charged sediments



N-S Transect of Grimsey Vent Field (07-17-99)

Fig. 2: Bubble plume caused by active venting in the Grimsey hydrothermal field

- Hydrothermal plume mapping by water-column sampling
- In-detail investigation of the Grimsey vent field including:
  - Sampling of gases and vent fluids using the manned submersible JAGO.
  - Investigation of the type and the extent of hydrothermal mineralisation.
  - Estimating the biodiversity of anaerobic and aerobic bacterial communities.

2. Report on the cruise with technical results

R. V. POSEIDON left Reykjavik at 5 p. m. on 9 July. On 11 July POSEIDON reached the working area around Grimsey Island. In general diving, coring, dredging, and hydrocast stations were run during the day, whereas profiling was done during the night. Diving operations (up to two dives per day) were conducted whenever weather conditions were good. In total 7 dives, 9 hydrocast stations, 13 dredge stations, 19 coring and 20 profile stations were conducted (see station list in

Fig. 3: Locations of echsounding profiles near Grimsey

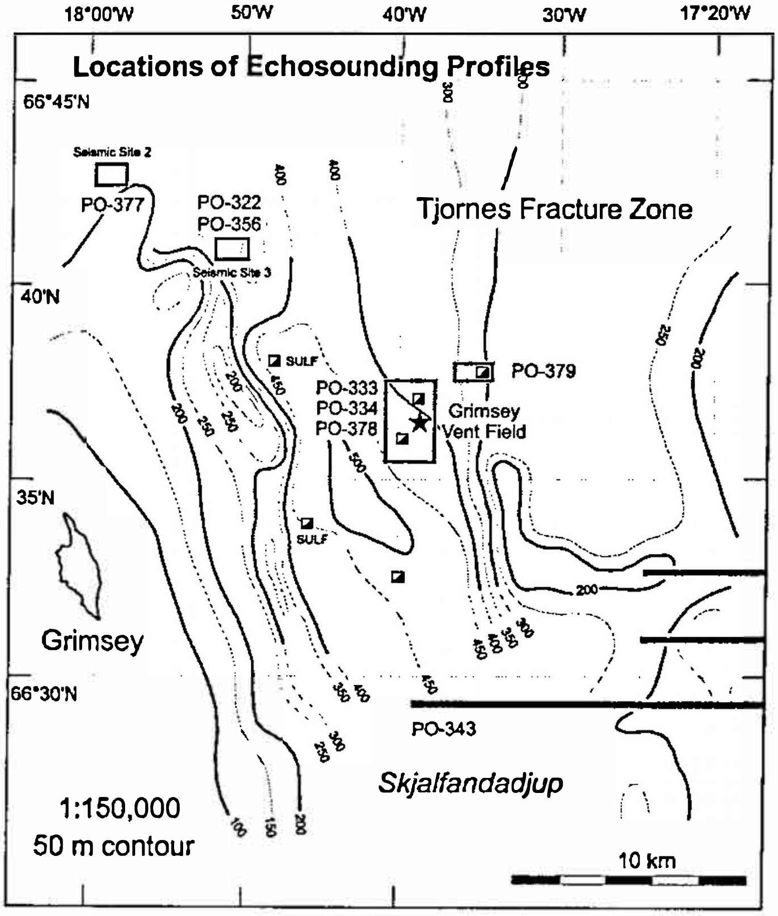
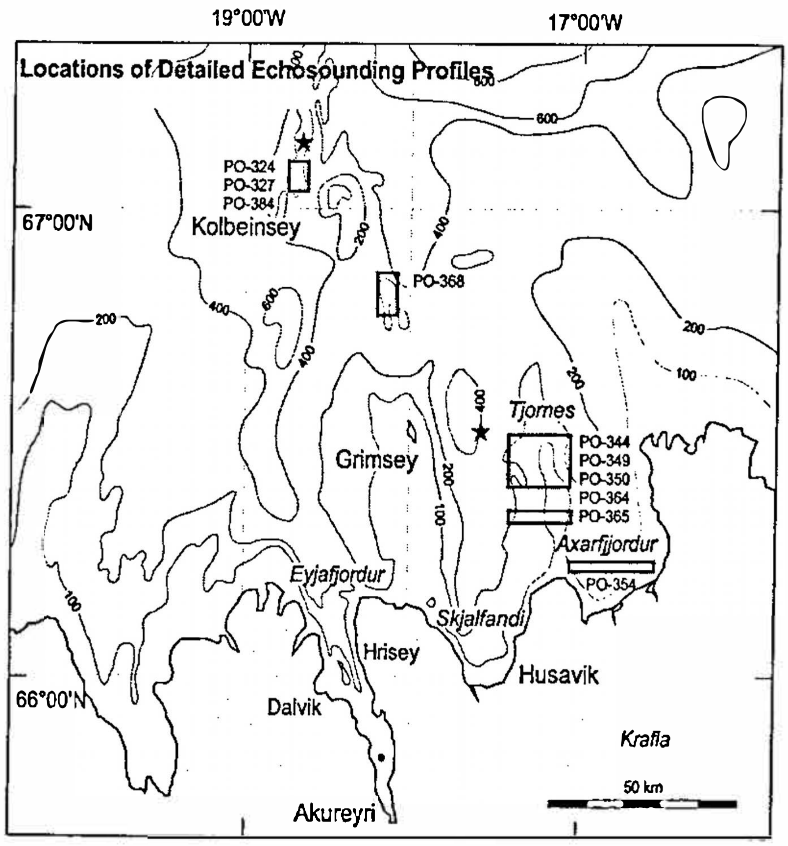


Fig. 4: Locations of echosounding profiles between Kolbeinsey and Axarfjjordur



appendix). A short stop was made for the exhange of two scientific crew members on 15 July. The cruise ended on 22 July in Reykjavik.

3. Scientific report and first results

3.1 Profiling

In order to find areas with active hydrothermal activity extensive profiling using echosounding and fishfinder systems were carried out during the cruise. As was observed during Poseidon cruise 229 in 1997, active venting can cause a strong signal in the water column which could be recorded by the echsounding systems (Fig. 2). Profiling was done in areas where recent seismic activities had been recorded (Rögnvaldsson et al., 1998). Additional areas were chosen based on the on-board interpretation of reflection seismic lines obtained during POSEIDON cruise 252 (see Figure in appendix). The profiled areas are shown in figures 3 and 4. Strong signals indicating hydrothermal activity could only be recorded in the Grimsey and Kolbeinsey hydrothermal fields.

3.2 JAGO Dives

Detailed diving in the Grimsey Hydrothermal Field (Tab. 1) was conducted in order to map the hydrothermally active area in detail (see diving logs in appendix). Several new vent sites were observed (Fig. 5) and vent fluids and hydrothermal precipitates were sampled for further analysis (see chapters...). In general the southern Grimsey Hydrothermal Field is characterized by several individual anhydrite mounds which consist of thinly sediment-covered anhydrite rubble. On top of the mounds, several up to three meter high anhydrite chimneys were observed which were surrounded by collapsed chimneys (Fig. 6). All of the measured vent temperatures range 248° and 251°C, which is the boiling temperature at the given depth and visible phase separation was noted at the vent outlets. No macro-fauna associated with the hydrothermal vents was observed. The absence of abundant filamentous bacteria suggests that the sulfur contents of the fluids was low. Some white patches of bacteria (probably *Beggiatoaceae*) occurred in the sediments adjacent to the mounds. The vent sites at the southernmost ridge are probably in a waning state of hydrothermal activity because due to the occurrence of (i) only small chimneys with relatively low discharge rate, (ii) one apparently inactive (or totally sealed off) anhydrite mound without any chimneys, and (iii) one old and almost completely dissolved and extinct vent site. No typical macro-fauna associated with the hydrothermal vents was found.

One further dive was conducted near Tjoernes Peninsula where echosounding records showed bubble or plume like features above a hard reflector at the seafloor. Diving in this area revealed ripple marks on top of basaltic basement to be responsible for the observed echosounding records.

Table 1: Locations of diving operations

Station no.	JAGO Dive no.	Date	Submerged at Lat./Long	Time	Surfaced at Lat./Long	Time	Duration (min)	Depth max. (m)	Pilot	Observer	Sampling locations
323	632 (1)	11.07.99	N 66.36.55 W 17.39.16	10:35	N 66.36.45 W 17.39.12	14:40	245	405	Schauer	Hannigton	hydrothermal vent at 394m; gas, water, anhydrite chimneys
328	633 (2)	12.07.99	N 66.36.41 W 17.38.98	09:20	N 66.36.21 W 17.39.44	13:20	240	402	Schauer	Herzig	hydothermal vent at 399m; gas, water, anhydrite chimneys
366	634 (3)	17.07.99	N 66.26.89 W 17.10.32	08:30	N 66.27.14 W 17.09.09	10:10	100	87	Schauer	Scholten	Survey and ground-truthing at ridge of Tjörnes-Grunn
367	635 (4)	17.07.99	N 66.36.42 W 17.39.15	14:45	N 66.36.59 W 17.39.91	18:15	210	400	Schauer	Marteinsson	hydrothermal vent at 394m, recovery of bacteria traps, water, anhydrite chimneys
380	636 (5)	19.07.99	N 66.36.37 W 17.39.65	09:00	N 66.36.20 W 17.39.31	12:40	220	399	Schauer	Schmidt	hydrothermal vent at 377m, gas outlet at 380m, gas, water, anhydrite chimneys, red sulfid rock
382	637 (6)	19.07.99	N 66.36.27 W 17.39.64	16:58	N 66.36.18 W 17.39.21	20:40	222	399	Schauer	Preißler	Hydrothermal vent at 377m, gas, water anhydrite chimneys, backed clay
386	638 (7)	20.07.99	N 66.36.41 W 17.39.44	13:30	N 66.36.58 W 17.39.05	17:00	210	405	Schauer	Scholten	Hydrothermal vent at 394m, gasoutlet at 382m recovery of 2 bacteria traps, gas, water

Fig. 5: Locations of vents sites observed during Poseidon cruises 229 and 252

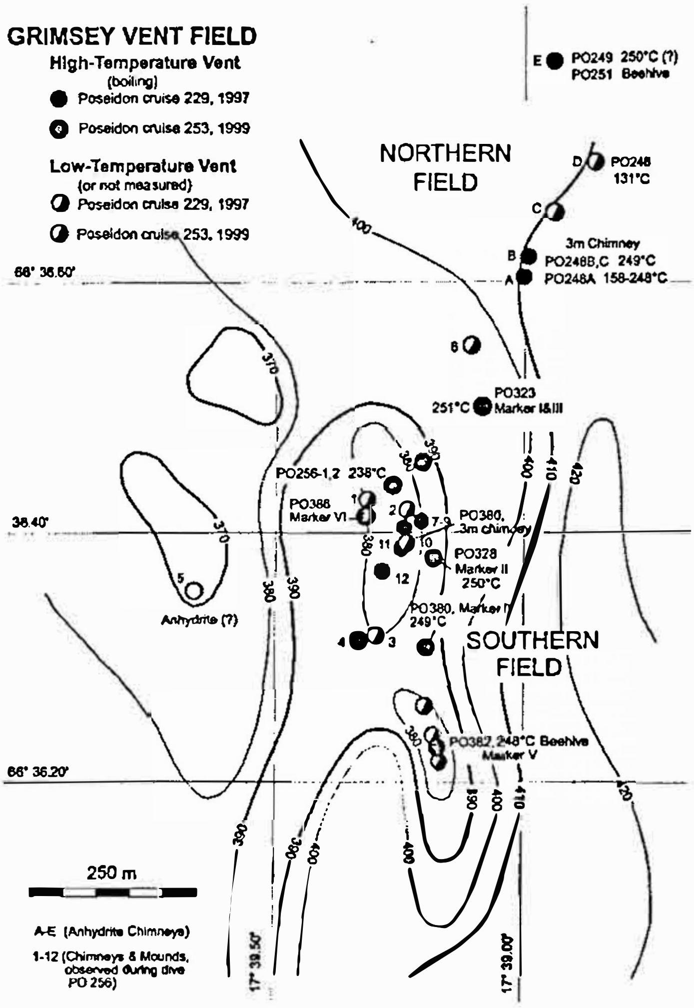


Fig. 6: Anhydrite mounds in the Grimsey hydrothermal fieled

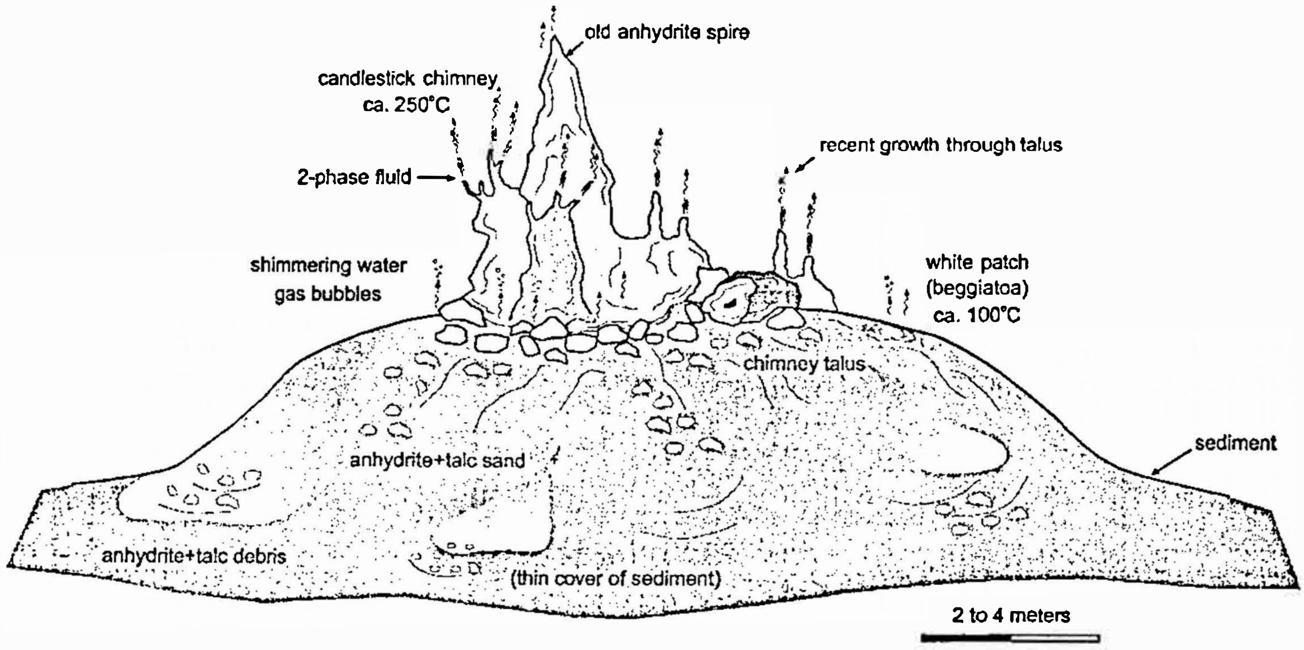


Table 2.1: Water- and gas-samples from Jago

Number	Station	Area	Depth	Sample	Temper.	Total Gas	Methane	Ethane	Propane	Methane	C1/C2
			[m]		[°C]	[ml]	{ppm}	[ppm]	[ppm]	[nl/l]	
1	323 Jago	Grimsey Vent Field	390	Free Gas		320.0	86904.9	666.9	146.1	---	130.3
2	328 Jago	Grimsey Vent Field	387	Free Gas		200.0	46721.7	323.2	---	---	144.6
3	328 Jago	Grimsey Vent Field	387	Water	250	36.3	15383.4	225.1	8.6	558418	68.3
4	367 Jago	Grimsey Vent Field	392	Water	20	31.5	1864.8	25.7	2.4	58742	72.6
5	380 Jago	Grimsey Vent Field	378	Water	250	21.9	651.6	4.8	---	14270	135.8
6	380 Jago	Grimsey Vent Field	380	Free Gas	0.6	200.0	88806.3	426.4	47.5	---	208.3
7	382 Jago	Grimsey Vent Field	376	Free Gas		400.0	77064.8	309.2	35.3	---	249.2
8	382 Jago	Grimsey Vent Field	378	Water	247	21.9	1491.2	13.7	---	32657	108.8
9	386 Jago	Grimsey Vent Field	390	Free Gas		1400	50310.7	321.3	26.2	---	

Table 2.2: Sediment samples

Number	Station	Area	Sed. Depth
			[m]
1	325 DR		
2	329 SL	Grimsey Vent Field	3.0
3	335 SL	Grimsey Vent Field	surface
4	335 SL	Grimsey Vent Field	3.0
5	337 SL	Grimsey Vent Field	1.6
6	337 SL	Grimsey Vent Field	3.0
7	339 SL	Grimsey Vent Field	3.0
8	367 Jago	Grimsey Vent Field	surface
9	370 SL	Grimsey Vent Field	surface
10	370 SL	Grimsey Vent Field	3.0

Table 2.3: Water samples for He (rare gas) extraction

Number	Station	Bottle	Depth
			[CL]
1	328 Jago		387
2	338 MS	5	150
3	338 MS	11	315
4	345 MS	4	326
5	346 MS	9	370
6	348 MS	11	380
7	351 MS	9	392
8	358 MS	8	370
9	358 MS	11	378
10	367 Jago		392
12	382 Jago		378
13	383 MS	9	120

Table 2.4: Samples for Microbiology

Number	Station	Area	Depth
1	323 Jago	Grimsey Vent Field	390
2	347 SL	Grimsey Vent Field	229cm
3	367 Jago	Grimsey Vent Field	392m
4	386 Jago	Grimsey Vent Field	390m

Target LRT-BE4-V3

3.3 Trace gases at the southern Kolbeinsey area

Hydrothermal vent sampling

Fluid samples for trace gas measurments were taken at the Grimsey Hydrothermal Vent Field using the common Niskin-bottle carried by JAGO (Tab. 2.1). In general the bottle was directly placed into the outflows. Free gas bubbles were collected using a water-filled (1.5 l) glass bottle (designed by M. Schmitt) connected to a funnel which was positioned above the gas stream. The water in the bottles was partly replaced by gas which further expanded during uplift. When JAGO reached the surface a diver closed the two valves of the sample bottle under water. The gas was released on board Poseidon into small evacuated glass-bottles for further studies.

Water samples from Niskins (JAGO and Hydrobios-Water-Sampler) were degassed on board applying a combined ultrasonic/ vacuum degassing technique (Schmitt et al., 1991). Compositional analyses of light hydrocarbons (C_1 - C_6) of the gas samples were determined on-board with a Perkin Elmer Gaschromatograph Series 8700 (50 m long $Al_2O_3^-$-KCl PLOT^R quartz capillary column; flame ionization detector). Carbon isotope analyses of hydrocarbons will be performed by "continous flow isotope ratio analysis" (CF-IRMS) at GCA, Sehnde-Ilten.

Gas and water samples collected during JAGO-dives (Tab. 2.1) showed large enrichments in methane and higher hydrocarbons. The gas sampling rate was approximately 10 - 280ml (1 atm) per minute. Highest methane concentrations collected during PO253 were were half the concentrations collected two years ago on the same site (Botz et al. 1999). The C1/C2-ratio has changed to higher values (up to 250), possibly reflecting changed fluid migration pathways or sub-bottom conditions.

Sediment samples were collected from cores (0-3m) of the Grimsey Hydrothermal Vent Area (Tab. 2.2) for hydrocarbon gas measurements (adsorbed and total gas analyses).

Water samples for helium isotope analyses were taken from JAGO- and Multisonde-Niskins (Tab. 2.3). These samples for helium isotope analyses were stored in pinch-off copper tubes. We avoided contamination of the helium water samples as we did not use helium stripping techniques on board (compare above). Helium (rare gases) will be measured by Gisela Winckler (Umweltphysik, Heidelberg).

Small pieces of anhydrite/talc-chimneys were collected for fluid inclusion investigations.

Four samples of anhydrite chimneys from GHF (Tab. 2.4) were stored in 50ml glass bottles filled with fluids from GHF for microbiological investigations (R. Huber, Regensburg).

Hydrothermal plume mapping

Nine Multisonde(MS)-stations sampling the vertical water column were performed in the southern Kolbeinsey ridge area. Water samples were taken down to 7m above sea bottom. The results are listed in table 2.5. Low concentrations of methane usually <30nl/l which was the background methane concentration in this area were determined at four locations. No new hydrothermal field (postulated by on board interpretation of seismic reflection patterns during PO252) could be confirmed by methane anomalies. Only a slight increase in methane of about twice the background near the sea bottom was detected in water samples of station MS383 at KHF. Probably large water mass exchange and/or methane oxidation in oxygen rich sea water was responsible for this lack of methane in this known hydrothermal active area. Helium measurements of these samples will give further information.

Fig. 7: Locations of "Multisonde" Stations in the Grimsey Hydrothermal field

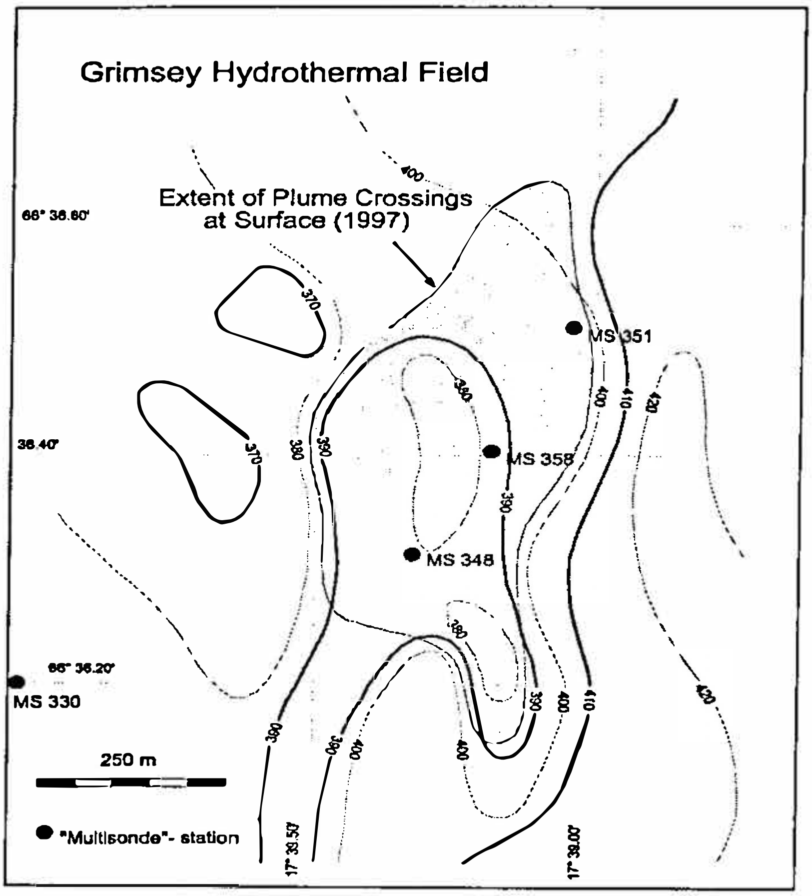
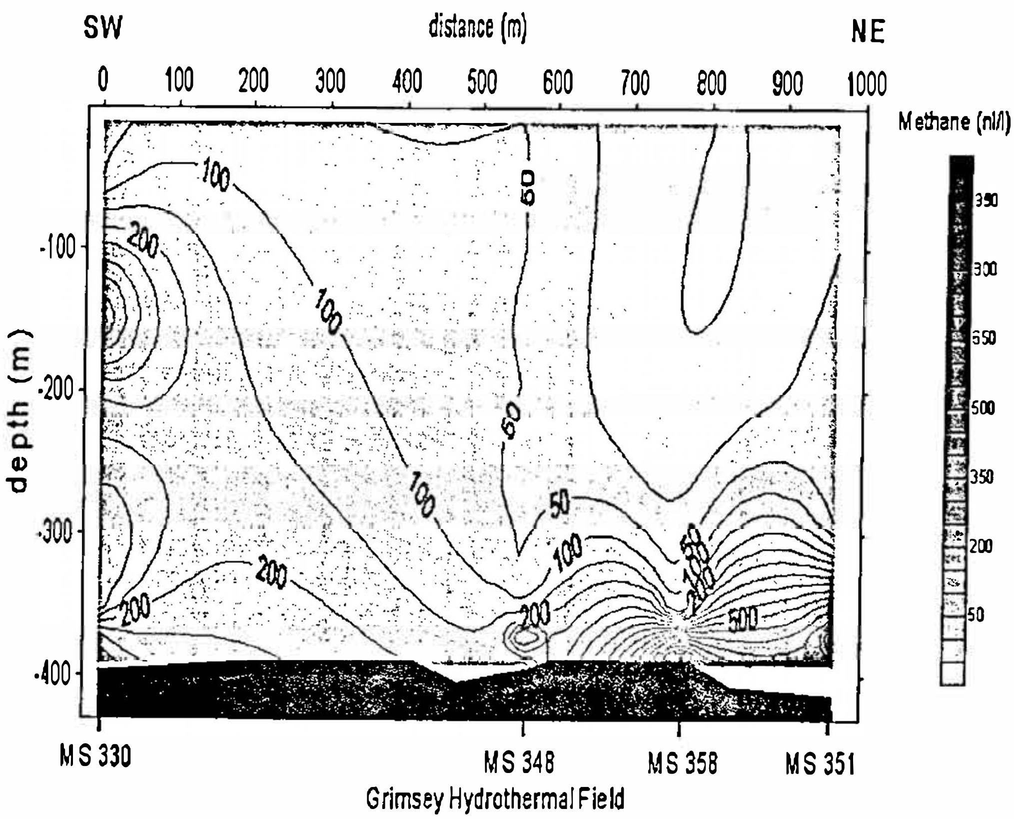


Fig. 8: Methane plume distribution in the Grimsey hydrothermal vent area



The East Grimsey Hydrothermal Field was investigated with 4 MS-stations (Fig. 7). The distribution of methane is plotted in a contour plot (Fig. 8). Large methane anomalies of about 1000nl/l occurred near the sea floor, although only background concentrations were detected above 300mbs. Isotope measurements ($\delta^{13}C$, D/H) of the hydrocarbons will give further information about the degradation processes in the water column.

3.4 Water sampling for trace elements and natural radionuclides

An inert pumping system was used for sampling of up to 6 samples during one dive. Using the manipulator of the JAGO submersible a mantled PFA (perfluoralkoxy) -Teflon tube was held into the vent fluids. This Teflon tube was connected to a titanium multivalve distribution line allowing to fill 6 sample tubes independently by opening or closing valves in the distribution line. Valve spindles, and connectors (SERTO jacob, Germany) were made of PTFE-(polytetrafluorethylene) teflon and PVDF, respectively. The samples were taken in PFA teflon tubes of 2 m length with a volume of approx. 250 ml wound around a plastic support. The pump was positioned downstream avoiding any contamination from it. In addition, a 5 l Niskin bottle which was attached to a frame on the front-end of JAGO was used for sampling larger volumes of water. The Niskin bottle was manoeuvred close to the outlet of venting fluids, and released. Fluid samples from the pumping system were filled in pre-cleaned 125ml PFA teflon bottles using nitrogen pressure. Further sample preparation on-board ship were performed in a class 100 clean bench. Any air contact of the samples was avoided. An aliquot for determination of total recoverable elements (dissolved and particulate) were taken from the sample and acidified with subboiled nitric acid. The remaining sample volume was pressure-filtrated through 0.4μm Nuclepore filters using nitrogen 5.0 (99.999 % N2). Filtrates were split for on-shore determination of anions, and major and trace elements. The latter aliquot was acidified with 5 drops of subboiled nitric acid. Samples from hydrocasts were treated in an analog way.

For the determination of natural radionuclides in the hydrothermal vents Mn-impregnated acryl fibres were placed in a PFA column (volume 150ml) which was mounted on the frame of JAGO. The column was attached to a pump on one side and to a 1.5m long Teflon tube, which was held by the manipulator of JAGO into the venting fluids on the other side. In addition water samples were taken from the Niskin bottle. A list of water samples taken during JAGO dives is shown in Table 3.

3.5 Sampling of rocks, sediments and hydrothermal precipitates

Seafloor sampling at the Grimsey hydrothermal vent field was conducted by using the submersible "JAGO", dredge hauls, and gravity cores. From six JAGO dives samples from the hydrothermal mounds were obtained. A network of 17 gravity cores were deployed in the northern field (2 cores) and southern field (13 cores in the main area, 2 cores in the hill structure south of it, see figure 9). A total of 13 dredge hauls was conducted at Skjalfandadjup Trough and near the Grimsey vent field in 368m to 482m water depth on search for hydrothermal material.

Samples recovered during JAGO dives from active anhydrite vents and mounds **(PO 323, PO 328, PO 367, PO 380-2, PO 382-6)** consisted almost of soft and friable anhydrite. The fluid channels were lined by pinkish-brown to pale yellow botryoidal talc. Some black material (pyrite? pyrolized bacteria?) was dispersed in the outer walls of the samples. Material recovered from an old, inactive hydrothermal mound area represented a rusty, strongly weathered relicts of fluid channelways consisting of pyrite and anhydrite (now gypsum) **(PO 380-1)**, a residual anhydrite

Table 2.5: "Multisonde"-stations

Station:	330 MS	Position: 17°39,943' W 66°36,217' N, Depth: 400m	
Depth [CL]	**Total Gas** [ml]	**Methane** [ppm/ml]	**Methane** [nl/l]
50	18.8	<1,5	<50
150	21.5	22.3	480.1
200	23.5	8.7	204
300	34.0	<1,5	<50
350	27.5	<1,5	<50
380	50.0	8.0	402
390	try again!		

Station:	338 MS	Position: 17°47,491' W 66°33,902' N, Depth: 320m	
Depth [CL]	**Total Gas** [ml]	**Methane** [ppm/ml]	**Methane** [nl/l]
50	33.6	<1,5	<50
100	22.0	<1,5	<50
150	55.5	<1,5	<50
200	43.3	<1,5	<50
250	24.5	<1,5	<50
300	36.5	<1,5	<50
310	21.1	<1,5	<50
315	24.1	<1,5	<50

Station:	345 MS	Position: 017°51,29' W 66°41,00' N, Depth: 338m	
Depth [CL]	**Total Gas** [ml]	**Methane** [ppm/ml]	**Methane** [nl/l]
100	26.0	<1,5	<50
200	55.5	<1,5	<50
290	20.5	<1,5	<50
320	20.5	<1,5	<50
326	21.7	<1,5	<50

Station	346 MS	Position: 17°58,53' W 66°42,63' N, Depth: 381m	
Depth [CL]	**Total Gas** [ml]	**Methane** [ppm/ml]	**Methane** [nl/l]
100	32.0	<1,5	<50
150	18.0	<1,5	<50
200	20.3	<1,5	<50
330	45.5	<1,5	<50
360	55.5	<1,5	<50
370	47.7	<1,5	<50

Station:	348 MS	Position: 17°39,281' W 66°36,245' N, Depth: 387m	
Depth [CL]	**Total Gas** [ml]	**Methane** [ppm/ml]	**Methane** [nl/l]
10	21.7	<1,0	<30
50	21.7	<1,0	<30
100	21.7	<1,0	<30
200	16.0	<1,0	<30
300	31.0	<1,0	<30
350	19.5	<1,0	<30
360	20.7	12.8	264
375	25.7	22.4	576
380	40.0	<1,0	<30

Station:	351 MS	Position: 17°39,062' W 66°36,499' N, Depth: 408m	
Depth [CL]	**Total Gas** [ml]	**Methane** [ppm]	**Methane** [nl/l]
200	34.0	<1,0	<30
300	22.3	<1,0	<30
360	21.3	31.9	680
370	22.5	46.3	1041
375	21.5	28.5	613
380	47.5	16.6	786
385	23.1	23.5	543
390	22.2	19.0	422
392	24.9	28.2	702

Table 2.5 continue

Station:	358 MS	Position: 17°39,199' W 66°36,408' N, Depth: 389m		Station:	383 MS	Position: 18°42,945' W 67°05,399' N, Depth: 139m		Station:	385 MS	Position: 18°44,007' W 66°57,322' N, Depth: 334m	
Depth [CL]	**Total Gas [ml]**	**Methane [ppm/ml]**	**Methane [nl/l]**	**Depth [CL]**	**Total Gas [ml]**	**Methane [ppm]**	**Methane [nl/l]**	**Depth [CL]**	**Total Gas [ml]**	**Methane [ppm]**	**Methane [nl/l]**
330	41.0	1.6	65	**50**	21.5	<1	<30	**100**			
340	44.0	1.1	50	**70**	22.1	<1	<30	**200**	38.0	4.3	164
350	21.5	4.9	104	**80**	>50	<1	<30	**300**	38.0	1.6	59
360	21.6	4.8	103	**90**	19.7	<1	<30	**350**	21.3	1.6	35
365	35.5	7.6	270	**100**	22.6	<1	<30	**405**	21.3	1.2	26
370	21.5	26.5	570	**110**	24.9	<1	<30	**410**	23.5	2.3	54
375	25.7	32.8	844	**120**	50.5	1.3	67	**415**	25.9	2.0	53
378	33.6	31.6	1063	**135**	39.1	<1	<30	**422**	23.3	<1,0	<30

Table 3: Water samples taken during JAGO dives for trace elements and radionuclides

Station no.	**Submerged Lat. (N) Long. (W)**	**Surfaced Lat. (N) Long (W)**	**Depth max.(m)**	**Sampling locations: Trace element pumping system**	**Radiotracer pump sample**	**Niskin sample**
323	66°.36.55 17°.39.16	66.36.45 17.39.12	405	samples from vent marked I temperature: 251°C	same location as trace elements	-
328	66°.36.41 17°.38.98	66.36.21 17.39.44	402	samples from vent marked II temperature 250°C	same location as trace elements	same location as trace elements
367	66°.36.42 17°.39.15	66.36.59 17.39.91	400	samples from vent marked I	same location as trace elements	20 cm above diffusive vent
380	66°.36.37 17°.39.65	66.36.20 17.39.31	399	samples from vent in the vicinity of vent marked IV	same location as trace elements	same location as trace elements
382	66°.36.27 17°.39.64	66.36.18 17.39.21	399	vent marked V temperature 248°C	mound 2, north of vent V	same location as radiotracers
386	66°.36.41 [illegible]	66.36.58 [illegible]	405	samples from vent marked I [illegible]	ambient bottom [illegible]	-

crusts (now partly gypsum) **(PO 382-1)**, a finely layered siliceous sinter with residual anhydrite enclosing red ochre material (perhaps formerly a pyritic sulfide pod) **(PO 282-2)**, a silicified anhydrite (now gypsum) sinter **(PO 382-3)**, reddish hematitic material (could be an indurated mud from which silica has been removed and replaced by iron hydrolysates) **(PO 382-4)**, and a brown mud brick composed of bioturbated sediment material **(PO 382-5)**.

Gravity cores located in the northern field **(GC 340, GC 373)** recovered a thick layer of green-brown pelagic sediment (3m) with temperatures of the sediments in the core catcher between 36°C and 31°C (measured on deck).

Gravity cores **GC 337, GC 339, GC 369, GC 370, GC 372, GC 374**, and **GC 381** were deployed within the central boiling zone (Fig. 10) of the southern hydrothermal field. Temperatures measured in the core catchers ranged between 65°C to 102°C and some seawater trapped in the sediment cores was still boiling when the core hit the deck (see appendix, plate a).

The base of core **GC 337** was composed of indurated mud with up to 2% of impregnated minute pyrite flakes and stringers. From 190 to 235cm sediments constisted of hydrothermally altered hyaloclastite beds containing gravel-sized grains of variably altered holocrystalline basalts which were mixed with fine grey mud and finer pyrite (dispersed in the muddy matrix). This highly altered zone was overlain by indurated brown-green mud (115 to 185cm) characterized by increasing hardness due to increasely intensity of alteration and dehydration with increasing depth. This pelagic mud zone was cut by a vertical veins or fractures with the vein margins bleached and altered. This structure possibly represents an area of fluid upflow from a hydrothermal aquifer to the former sediment surface. The upper part of the sediment cores was composed of a mixture of unsorted debris flows consisting of anhydrite sand, anhydrite gravel, anhydrite clasts, and brown-green mud set the highest sediment layer.

The upper part (0 to 55cm) of core **GC 339** was made up by green-brown pelagic ooze underlain by several thin layers of anhydrite clasts in dehydrated mud. The underlying complex sequence included soft mud and dehydrated patches. Lighter grey zones indicate possible fluid pathways. The base of the core consisted of a blue-grey alterated mud layer with patches of black material (sulfides?).

The uppermost 1 to 2m of core **GC 369** was lost due to superpenetrating of the coring device. Sediment temperature of the core top was about 63°C, at the base about 101°C. Strongly dehydrated olive-green to brown mud (0 to 150cm) was veined by softer pale brown mud and blue-grey mud within a zone of well-developed alteration veins (75 to 112cm). The pervasive clay alteration was controlled by anastomosing networks of fractures. Mineralization in the form of pyrite veins occupied the cores of altered clay "veins" as discontinous veinlets, tiny vug infill, and dense disseminations. The basal debris flow (240 to 210cm) consisted of sandy talc grading downward into coarser gravel with recrystallized anhydrite, blue-grey clay, and disseminated pyrite.

Core GC 370 recovered a hydrothermal aquifer (215 to 240cm) consisting of 85% anhydrite (+talc) breccia and 15% pale grey mud matrix. Considerable amounts of free pyrite (needles, blades, flakes, tubular dendrites) were embedded in recrystallized anhydrite at base of core and indurated, hydrothermal altered mud above it (35 to 215cm). Dark green pelagic ooze (0 to 35cm) represented the top. Sediment temperatures of about 100.6°C were measured in the core catcher.

Core GC 372 was topped by olive-green to brown pelagic ooze (0 to 75cm) and dark green-brown hardened mud (75 to 85cm). From 100 to 300cm the core contsisted of hydrothermally altered mud with disseminated pyrite and some rhombic crystals (barite?). A most strongly altered section (110 to160cm) was characterized by blue-grey altered mud with irregular patches of amorphous brown talc. From 165 cm to 300cm sediments were weakly banded containing soft granular pale brown talc and blue-grey claystone layers which are progressively hardening

Fig. 9: Locations sediment cores

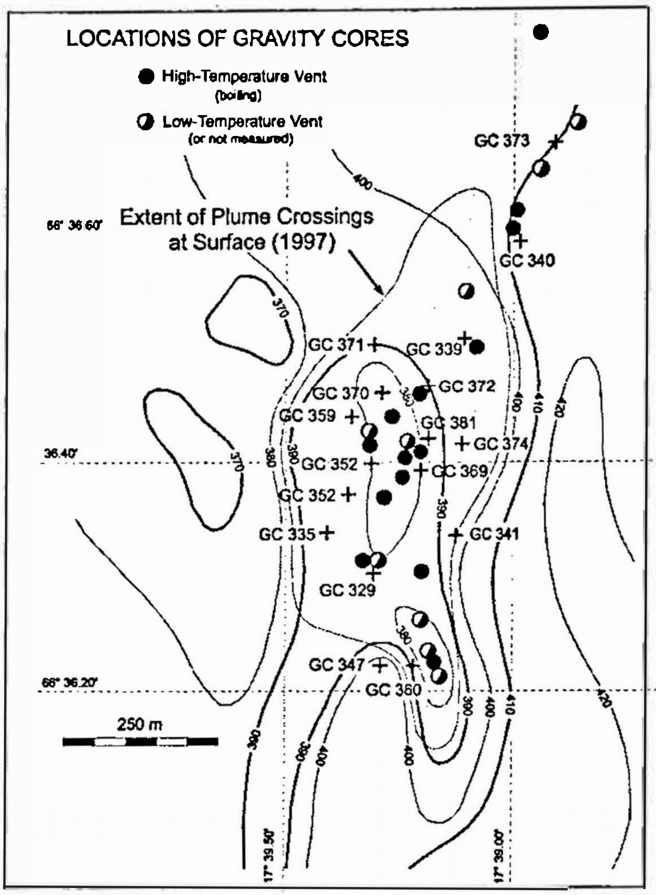
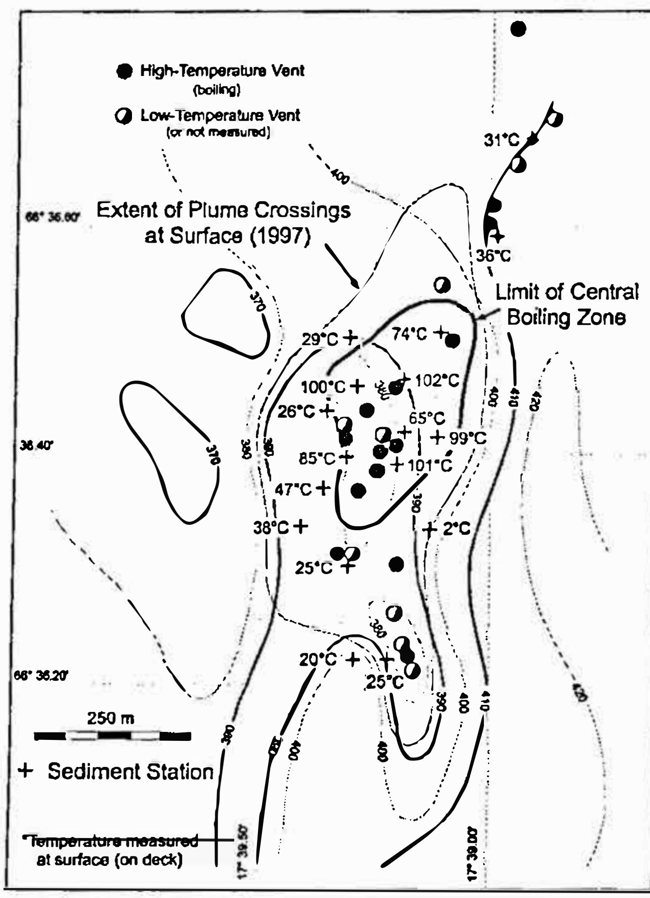


Fig. 10: Temperatures at bottom of the 3 m cores



towards the base of the core. Boiling seawater was observed when the core hit the deck of the ship.

Core **GC 374** represented a 3m-section of hemipelagic mud and hydrothermal alteration of that material was characterized by increasing dehydration downwards. A vein of light brown altered mud (softer than surrounding baked mud) probably signed a fluid pathway. Blue-grey baked mud (240 to 300cm) contained disseminated pyrite and clots of amorphous brown material (talc?).

Gravity cores **GC 329, GC 335, GC 341, GC 352, GC 359**, and **GC 371** penetrated the outer area around the boiling zone of the southern vent field. Temperatures measured on deck in the core catchers ranged from 2°C to 47°C. The cores GC 329, GC 341, and GC 352 recovered 3m of a thick sequence of green-brown pelagic and turbiditic muds. GC 335, GC 359, and GC 371 were topped by pelagic green-brown mud as well, but core catchers ended in hydrothermal altered, dehydrated mud with traces of basaltic glass (1 to 2%), pyrite, and other dark heavy minerals (magnetite?).

Cores GC 347 (temperature of 20°C of sediments in the core catcher) and **GC 360** (temperature of 25°C of sediments in the core catcher) were deployed on the flanks of the southernmost ridge-like structure of the Grimsey hydrothermal field. **GC 347** was dominated by several anhydrite debris flows and a poorly developed proximal turbidite sequence. Each discrete flow showed evidence for a fining upwards cycle which is typical for proximal turbidite and debris flows.

GC 360 recovered 40 cm of gravel sized, unconsolidated material consisting of approximately 30 to 40% talc (botryoidal, pink to white) and 50 to 60% anhydrite (white). A few pieces of the gravel were reddened by iron oxide. An indurated layer consisted of pink talc, white hard anhydrite,some thin black shards (0.5 to 1cm), and some suspected quartz. This indurated layer cemented indiscrete anhydrite grains to produce a hard conglomerate up to 5cm thick. One bigger piece was cut and exposed about 40% botryoidal talc seemingly replacing bladed anhydrite.

Dredge hauls recovered subrounded glacial basalts **(DR 325-1, DR 336-2, DR 375)**, basalt fragments with Fe-oxide-crusts **(DR 331-2, DR 336-2)**, basalts with rinds of relatively fresh glass **(DR 336-2)**, basalts with quartz crystals and stilbite (?) in small voids **(DR 357)**, pale grey-green and brown-reddish mudstones with lots of worm channels about 0.4mm in diameter **(DR 325-2, DR 331-1, DR 336-1, DR 375)**, and three different kinds of small seastars. No hoped-for sulfidic material was dredged.

Detailed descriptions and distribution of samples, core profiles, and summaries are presented in the appendix.

The material recoverd during Poseidon 252 allows a first interpretation of the structure and genesis of the Grimsey Hydrothermal field as follows: The areas of active venting is underlain by pelagic, clastic and hydrothermally altered sediment sequences. Multiple sulfate debris flows (anhydrite clasts, gravel, and sand + talc) separated by hemipelagic and turbiditic sediments indicate several stages of sulfate chimney formation, collapse, and resedimentation. The shedding of anhydrite and hemipelagic sediments from the mounds may have been triggered by seismic activity associated with tectonic or magmatic events.

Expected sulfide deposition was proved in the shallow subsurface (between 2 to 3m) by sediment cores containing mineralizations in the form of pyrite veins and disseminations of pyrite within hydrothermal aquifers and altered layers of clay and mud. Furthermore, these hydrothermally altered sequences are characterized by amorphous brown patches of talc-like minerals of contentious origin. Possibly, fluids carrying Mg and Si derived from a nearby upflow zone had altered the pelagic mud to such an extent as to synthesise talc or its precursors. Mixing of fluids with cold seawater drawn into the shallow subsurface resulted in magnesium metasomatism and hydrolytic alteration of the sediments (Zierenberg and Shanks, 1993). Alternatively, due to the retrograde solubility the alteration of anhydrite debris flows may favour the enrichment of talc and clay minerals. This mechanism would explain the generation of clay-talc interlaminations.

Detailed and careful evaluation of gravity cores leads to the following model:

Target LRT-UE4-V3

Hot fluids from the hydrothermal upflow that feed the chimneys percolate laterally away from the anhydrite mounds and follow the most permeable horizons within the underlying mud-sand sequences. These are usually debris flows of anhydrite fragments from nearby chimneys and pelagic mud. The hydrothermally altered aquifers are characterized by coarser gravel of anhydrite, talc, blue-grey clay, and partly disseminated pyrite. High heat flow in these zones serves to dehydrate, bake and shrink the overlying hemipelagic mud (ca. 30% water) and permit hot water to rise into microfractures and sediment pores. The upflowing pathways of the fluids are characterised by anastomosing alteration veins which cut the overlying, weakly pyritic mudstone. Pyrite sometimes occupies the cores of these altered clay "veins" as discontinous veinlets, tiny vug infill, and dense disseminations. The coalescence of anastomosing networks of fractures permit the rise of ponded hot fluids and can create a chimney-like conduit towards the surface into which abundant sulfides can precipitate (cf. Middle Valley, Goodfellow and Franklin, 1993). The end result will be a pipe-like body of sulfides or more likely, an array of veins that may vent to form volcanogenic massive sulfide deposits (VMS), or form epithermal deposits below the seafloor.

Sulfide metal ratios (bulk geochemistry, microprobe analyses), as well as Pb, S and Sr isotope compositions of hydrothermal minerals should clarify the influences (basaltic crust, sediments, magmatic input) of hydrothermal fluids from which the deposit was formed. Oxygen isotopes can determine formation temperatures for certain mineral phases and may be helpful in resolving the question of the genesis of talc, talc-like gels and grains at the subsurface. Fluid inclusion work will check and maybe extend the criteria used for proofing phase separation in fossil ores.

3.6 Bio-diversity and microorganisms

The main objective during Poseidon 253 was to sample material from hot areas on the sea floor in order to study the bio-diversity of cultivated and non-cultivated microorganism as well as to cultivate anaerobic and aerobic microorganisms at high temperatures. For this purpose chimney and core samples were taken. Water samples were concentrated and some biomass was obtained from in situ traps.

On-board samples for cultivation have been stored under anaerobic and aerobic conditions at 4°C. Samples for DNA extraction were stored below -20°C.

Some water samples were concentrated by filtering and the biomass stored at – 20°C.

Three bacterial traps were successfully deployed on the sea floor at station no. 367 (400 m depth). Each trap was prepared just before diving. The first trap (yellow O ring) was deployed on dive 632 and then retrieved on dive 635. Two bacterial traps (trap 8 and 9) were deployed on dive 635 and retrieved on dive 638. A detailed list of samples is given in the appendix

For the future work it is planned to do some enrichments for anaerobic and aerobic thermophilic microorganisms from obtained samples and to isolate some strains from the enrichments. Partial sequence of the 16S rRNA gen will be analysed in some isolated strains and new species will be described.

DNA will be extracted from obtained biomass from bacterial traps, core samples and concentrated water samples. The phylogenetic diversity of the microbial community developed in the samples will be analysed with PCR amplification and partial sequence of the 16S rRNA gen will be analysed. The ratio between Bacteria and Archaea in samples will be estimated with whole cell hybridisation and universal probes for both kingdoms. Partial sequence of the 16S rRNA gen of free-floating bacteria in some water samples will be analysed as well.

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APPENDIX

List of stations

Diving tracks

Diving Logs

Sample descriptions

Core descriptions

Core logs

List of samples for bacterial analyses

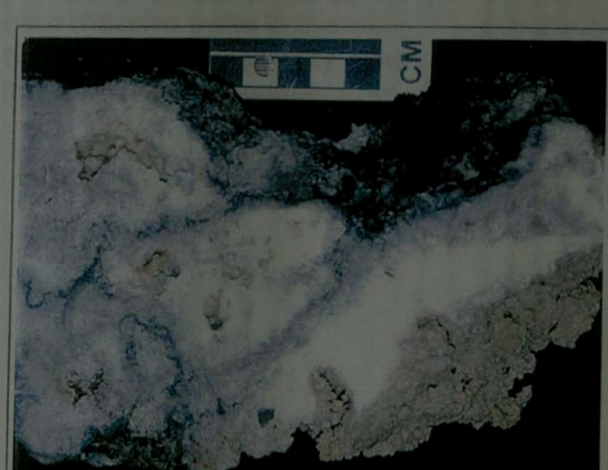
Photographs of sediment sequences and hydrothermal precipitates from East Grimsey vent field

a: GC 369 (core catcher)

b: GC 337 (61cm - 82cm) 28 mm

c: GC 372 (147cm - 159cm) 16 mm

d: GC 347 (112cm - 136cm) 30 mm



e: Sample PO 367 14 mm

f: Sample PO 380-1 12 mm

arget LRT-8E4-V3

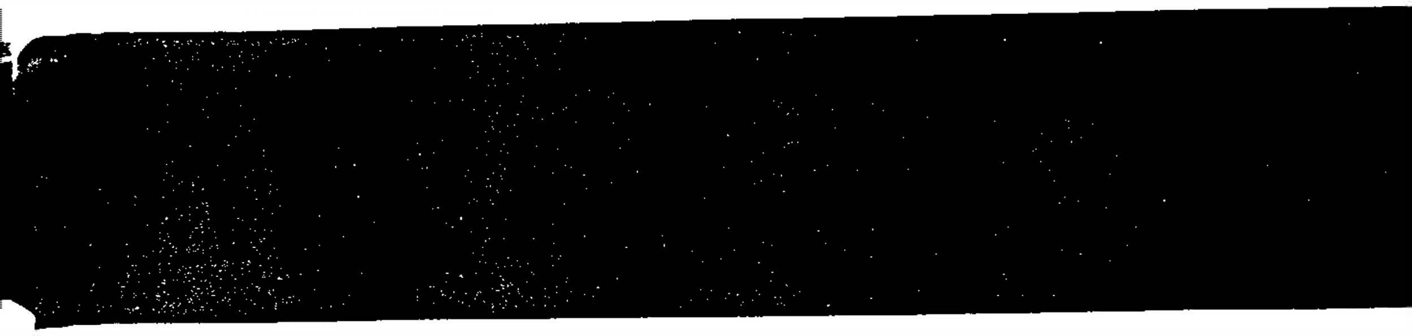


Plate description:

a: **GC 369**
Steaming core catcher with hot sediments (101°C) of gravity core GC 369. Some of the cores penetrated in the central "boiling zone" of the southern field of East Grimsey vent field were still boiling on deck.

b: **GC 337** (61cm – 82cm)
Typical mixture of brown-green pelagic mud, sandy anhydrite, gravel, and coarser lumps of anhydrite from debris flows of collapsed chimneys from nearby mounds. Anhydrite frequency decreases downwards due to its retrograde solubility.

c: **GC 372** (147cm – 159cm)
Highly altered zone consisting of blue-grey claystone and soft brown gelatinous patches and a few paler brown botryoidal (2cm) clots of talc. The section is semi-dehydrated (or perhaps rehydrated) and contains sparse disseminated pyrite. It is possible that intense Mg metasomatism has altered pelagic mud to such an extent as to synthesise talc or its precursors.

d: **GC 347** (112cm – 136cm)
The entire sequence consists of sand to gravel sized anhydrite grains distributed into alternating bands of coarse orange-brown and sandy buff white anhydrite. The rusty brown surface layer represents sulfide rubble oxidized to limonite exposed to seawater. The section can be subdivided into several discrete anhydrite debris flows and poorly developed proximal turbidite profiles formed in depressions on the side of slopes of hydrothermal mounds or ridges. Each unit shows evidence for coarse to finer upward deposition as typical for proximal turbidite and debris flows.

e: **PO 367**
The main fluid channel (ca. 10cm in diameter) of a 250°C fluids discharging vent is enclosed in white hard anhydrite and lined by pinkish-brown botryoidal talc, 1 to 3mm thick. Numerous small spigots were venting through a soft anhydrite. Black material (pyrolized bacteria? pyrite?) is coating the wall of chimney.

f: **PO 380-1**
Rusty, strongly weathered pyrite-anhydrite (now gypsum) conduit infill. clearly quite old. Texturally fine pyrite surrounds mm "anhydrite" grains and may have replaced these to form near massive pyrite in the walls. Fluid pathways are lined by botryoidal hard pyrite. The observation of other rusty lumps in the flat area suggest that this is now an inactive site and these are aged remnants from a sulfate mound long since dissolved away.

Station list

Station No.	Date	Time	Longitude (°W)	Latitude (°N)	Depth (m)	Work
321	11.07.99	02:32	17°54.24	66°40.91		Profile „Hydrothermalfield 3"
			to 17°49.93	to 66°40.91		
322		05:13	17°40.47	66°36.48		Profile South Grimsey
			to 17°39.32	to 66°3.95		
323		09:00	17°39.16	66°36.55	390	Dive JAGO (incl. test and buoy deployment)
324		15:00	17°39.0	66°36.8		Profile „Grimsey"
			to 17°38.92	to 66°36.85		
325		16:05	17°46.841	66°33.024	412	Dredge
326		16:27	17°46.956	66°33.030	406	Dredge
327	12.07.99	01:55	18°45.25	66°58.2		Profile „Hydrothermal-field I"
			to 18°44.7	to 66°57.8		
328		09:20	17°38.98	66°36.41	390	Dive JAGO (at buoy of St. 323)
329		13:41	17°39.316	66°36.402	391	Gravity-corer (3m)
330		14:30	17°39.943	66°36.217	400	CTD
331		15:50	17°48.196	66°17.998	459	Dredge
332		18:01	17°47.947	66°37.009	436	Dredge
333		21:09	17°38.0	66°36.6		Profile „North Grimsey"
			to 17°38.0	to 66°37.5		
334	13.07.99	02:38	17°38.5	66°36.1		Profile „South Grimsey"
			to 17°38.5	to 66°35.8		
335		09:22	17°39.468	66°36.380	395	Gravity-corer (3m)
336		10:10	17°37.07	66°36.56	384	Dredge
337		13:05	17°39.343	66°36.401	390	Gravity-corer (3m)
338		14:00	17°47.491	66°33.902	320	CTD
339		15:47	17°39.116	66°36.520	403	Gravity-corer (3m)
340		16:25	17°39.00	66°36.58	414	Gravity-corer (3m)
341		17:00	17°39.12	66°36.34	403	Gravity-corer (3m)
342		18:12	17°43.890	66°33.997	482	Dredge
343		19:56	17°41:00	66°31.87		Profile Tjornes
			to 17°35.16	to 66°31.88		
344	14.07.99	01:14	17°05.063	66°26.505		Profile
			to 17°30.12	to 66°26.47		
345		08:06	17°51.29	66°41.00	338	CTD
346		09:18	17°58.53	66°42.63	381	CTD
347		13:40	17°39.324	66°36.221	388	Gravity-corer (3m)
348		16:00	17°39.281	66°36.245	387	CTD

Station No.	Date	Time	Longitude (°W)	Latitude (°N)	Depth (m)	Work
349		18:17	17°13.0	66°26.9		Profile „Tjoernes Plume Area“
			to 17°13.0	to 66°26.5		
350		20:39	17°18.03	66°24.98		Profile „Tjoernes Peninsula““
			to 16°59.83	to 66°25.02		
351	15.07.99	15:32	17°39.062	66°36.499	408	CTD
352		16:13	17°39.128	66°36.373	399	Gravity Corer (3m)
353		18:09	17°34.931	66°36.409	486	Gravity Corer (5m)
354		21:48	16°49.99	16°29.947		Profile „Axarfjordur“
			to 66°16.01	to 66°15.01		
355	16.07.99	09:32	17°47.918	66°37.951	459	Dredge
356	16.7. (ctd.)	10:30	17°49.0	66°38.0		Profile (for Dredge Station 357)
			to 17°53.0	to 66°39.0		
357		13:46	17°49.539	66°38.974	417	Dredge
358		14:30	17°39.199	66°36.408	389	CTD
359		15:42	17°39.42	66°36.409	390	Dredge
360		16:35	17°39.239	66°36.221	385	Gravity Corer (3m)
361		17:07	17°39.56	66°36.41	392	Dredge
362		18:19	17°39.330	66°36.183	404	Dredge
363		19:38	17°51.096	66°37.970	373	Dredge
364		22:56	17°17.57	66°30.99		Profile „Tjoernes Grunn“
			to17°16.613	to 66°28.01		
365	17.07.99	02:18	17°27.612	66°27.983		Profile „Grimsey“
			to 17°20.91	to 66°31.03		
366		08:15	17°10.32	66°26.89	60	Dive JAGO Tjoernes
367		14:45	17°39.15	66°36.42	390	Dive JAGO Grimsey(incl. buoy deployment)
368		18:20	18°01.5	66°47.5		Profile „Hóll“
			to 18°17.0	to 66°53.5		
369	18.07.99	10:43	17°39.229	66°36.386	391	Gravity Corer (3m)
370		13:00	17°39.28	66°36.44	390	Gravity Corer (3m)
371		13:55	17°39.26	66°36.49	394	Gravity Corer (3m)
372		14:45	17°39.17	66°36.45	391	Gravity Corer (3m)
373		17:23	17°38.809	66°36.716	412	Gravity Corer (3m)
374		18:32	17°39.109	66°36.416	398	Gravity Corer (3m)
375		19:01	17°46.00	66°35.003		Profile for Dredge
			to 17°47.5	to 66°35.01		
376		19:48	17°46.89	66°34.76	368	Dredge

No.	Date	Time	Longitude (°W)	Latitude (°N)	Depth (m)	Work
377		21:34	17°56.067	66°42.478		Profile „Nafir“
			to 18°03.53	to 66°44.48		
378	19.07.99	02:39	17°40.847	66°35.708		Profile „South Grimsey“
			to 17°34.4o	to 66°37.90		
379		06:23	17°34.57	66°40.11		Profile „Northeast Grimsey“
			to 17°34.30	to 66°40.09		
380		08:50	17°39.65	66°36.37	380	Dive JAGO Grimsey
381		14:17	17°39.21	66°31.41	388	Gravity Corer (5m)
382		16:45	17°39.64	66°36.27	392	Dive JAGO Grimsey
383	20.07.99	01:30	18°42.945	67°05.399	139	CTD
384		03:27	18°44.48	67°05.428		Profile „Hydrothermalfield 1“
			to 18°42.21	to 66°57.09		
385		06:15	18°44.007	66°57.322	334	CTD
386	10.7.99	13:30	17°39,44	66°36,41	405	Dive JAGO Grimsey

STATION NO.: 323

JAGO Dive NO.: 632

Date:	July 11, 1999
Time:	10:30 - 14:13 GMT
Depth Range:	405 to 394 m
Pilot:	Jürgen Schauer
Observer:	Mark Hannington
LOCATION:	Grimsey Vent Field
Target Area:	Main part of bubble plume in southern Grimsey Vent Field.
Objective:	To relocate main part of Grimsey vent field and sample high-temperature vents for fluids and gases. The active vents in the main part of the field were located on the last dive in 1997 and were not sampled. This dive was intended to locate and sample the highest temperature vents.

Summary:

JAGO landed in 405 m of water, approximately 250 m north of the main vent field. After a short transit to the southeast, a large 10-m-diameter anhydrite mound was located at a depth of 394 m at the approximate location of vent #6 found originally during Dive 452 (Station PO-256) in 1997. The mound is steep-sided and circular, with a maximum relief of 3 m. It is capped by an active chimney complex (3-4 m in diameter) consisting of 1-2 m high anhydrite spires and smaller active vents. The main spires emit shimmering water and are covered by filamentous bacteria. The smaller active chimneys (20-30 cm high) occur at the base of the large spires and consist of multiple high-temperature outlets resembling candlesticks (with opening of less than 2 cm). The highest temperature measured in one vent was 251°C. The high-temperature outlets are characterized by narrow, 2-4 cm jets of two-phase fluid, indicating that the fluids are boiling. However, the only bubbles observed were emanating in intermittent streams from the rubble at the base of the chimney complex and not directly from the active vents.

The base of the chimney complex is littered with the rubble of collapsed spires. Large pieces of anhydrite chimneys up to 25 cm in diameter were found surrounding the vent complex. The smaller, boiling chimneys have grown through the rubble at the base of the chimney complex and appear to represent new growth. The upper part of the mound is covered by anhydrite debris and sand, with a thin veneer of pelagic mud. Numerous white patches of exposed anhydrite, locally with shimmering water, were observed at the top of the mound, up to 3 m from the chimney complex. The side of the mound is covered by pelagic sediment.

Several attempts were made to collect vent fluids in the highest-temperature flow, but the sampling device did not function properly. Gas bubbles were collected from a weak bubble stream at the base of the main chimney complex. 6 large, intact samples of anhydrite chimney material were collected, and the entire structure was captured on video. A bacterial trap was placed on a shimmering white patch about 3 m from the base of the chimney complex. Marker #1 was deployed at the base of the active chimney complex (best-fit location of vent from sub-positioning system is 66° 36.51', 17° 39.09').

Mapping and sub-positioning indicate that the sampled mound is located mid-way between the main Grimsey vent field and the northern vent field, about 100 m northeast of the main bubble plume. White patches of anhydrite found between the vent complex and the area of the main plume suggest that the substrate between the northern and southern part of the Grimsey field is mainly sediment-covered anhydrite.

DIVE LOG:

Time	Depth	Heading	Comments
1030	-	-	JAGO in water and being pulled toward target
1037	-	-	Diver capping the valve on the gas bottle
1040	-	-	JAGO released at 66° 36.550, 17° 39.163 approximately 10 m south of buoy
1047	100	-	Descending
1053	200	-	Descending
1106	405	230	On bottom. Tan-colored muddy bottom with widely spaced ripple marks. Turning to 230° toward pinger.
1109	405	235	Turning to SW to locate pinger. Heading up gentle slope. A few pieces of anhydrite occur in the sediment - possibly debris from a nearby mound.
1112	404	230	Still heading up a gentle slope. More anhydrite fragments on bottom, but heavily sedimented. Locally bioturbated sediment. Few shrimp.
1115	401.5	230	Traveled approximately 60 m SW. More anhydrite debris in sediment, indicating that we are approaching a vent. Setting up video camera.
1120	401.5	220	More anhydrite rubble on sediment. Larger pieces 5-20 cm (10 per m^2).
1124	397	210	Climbed 3-4 m onto large anhydrite mound, up to 10 m in diameter. Mapping from 1997 suggests that this site corresponds to vent#6 (50-60 m south of drop point).
1126	394	190	Stopped at top of mound, facing a large chimney complex with multiple spires up to 2 m high. Abundant shimmering water surrounds the complex, with bacteria coating the older, larger chimneys. Active hydrothermal venting occurs from several small candlestick chimneys from the base of the larger chimney complex. Visible "flames" of two-phase fluid are observed on each of the small candlestick chimneys (6-7 in total). Minor, intermittent bubbling of

			gas occurs from the base of the chimney complex, but no bubbles are observed from the highest temperature vents. The base of the chimney complex is littered with large pieces of collapsed chimneys up to 0.3 m in diameter. The largest spire is up to 2 m high, but does not have an active high-temperature vent. The larger spires are surrounded by shimmering water. The active vents appear to be new growths (up to 30 cm tall) through the debris surrounding the chimney complex. The upper part of the mound is covered by anhydrite sand from collapsed chimneys with a thin veneer of pelagic sediment. The top of the mound is 5-7 m in diameter and is steep-sided (steeper on SE flank than on NE flank and may be located on a fault scarp). Several white patches of exposed anhydrite occur at the edge of the mound. Shimmering water is observed above the white patches.
1155	394.3	190	Positioning on north side of mound to take samples at small high-temperature chimneys. Deployed Marker #1 on north side. Sampling tip of larger candlestick chimney (sample PO-323-1). The two-phase flame coming from the base of the chimney is now 3-4 cm long, but no bubbles are observed. A steady temperature of 251°C was attained in the throat of the chimney, with the temperature probe inserted fully into the 2-3 cm wide orifice.
1204	394.3	190	P1 vent fluid taken in the throat of the 251°C vent. Valve closed at 1211.
1212	394.3	190	P2 vent fluid taken 3 cm above the vent orifice (100-140°C). Valve did not stay open. Retried at 1214-1217.
1218	394.3	190	P3 vent fluid taken 10 cm above vent orifice (10-15°C). Valve did not stay open.
1221	394.3	190	P4 valve did not open.
1224	394.3	190	Trying P3 again, but valve would still not remain open.
1225	394.3	190	P5 valve did not open.
1227	394.3	190	P6 valve did not open.
1230	394.3	190	Pumping filter for 3 minutes in diffuse flow about 10 cm above the vent orifice (10-15°C).
1240	394.3	190	Measuring temperatures in flow above vent orifice (see above for measurements). Changing batteries in video camera.
1248	394.3	190	Collected 3 pcs. of fallen anhydrite chimneys (samples PO-323-2,3,4). Close-up video of active 251°C vent that was sampled (to 1255).
1259	394.3	190	Securing water sampler and temperature probe in basket.
1302	394.3	100	Positioning to deploy bacteria trap on white patch at edge of mound (west flank of mound). Trap deployed in shimmering water on 30-40 cm diameter white patch. Temperature probe is blocked by samples in basket and temperature cannot be measured. Earlier observations suggest that similar white patches have near-surface temperatures of up to 100°C.
1308	394.3	100	Repositioning bacteria trap at center of white patch.

1313	394.3	140	Positioning on north side of chimney complex to collect bubbles from intermittent bubble stream at edge of chimney structure.
1325	394.3	140	Sampling gas bubbles with funnel at base of large chimney complex. The bubble stream is intermittent and irregular, with only a few bubbles per minute. The bubbles appear to be trapped beneath the rubble, and a better bubble stream can be produced if the bottom is disturbed with the manipulator. The best bubbles were observed when JAGO first bumped into the top of the mound.
1350	394.3	140	Valve on gas bottle closed. Approximately 5 cm^3 of gas collected in the upper neck of the bottle. (This later expanded to about 3–4 times the original volume).
1355	394.3	140	Sampling flaming tips of several small candlestick chimneys (samples PO-323-5,6,7). In this orientation, we can see at least 10 individual candle-shaped chimneys with two-phase flames.
1403	395	180	Moving away from vent complex and heading south to test sub-positioning system (best-fit location of vent from sub-positioning system is 66° 36.51', 17° 39.09'). Bottom drops off steeply to the south.
1408	400	180	Traveled approximately 50-60 m south of vent. Several small white patches observed in the sedimented bottom (patches up to 50 cm diameter). One white patch has a solitary anhydrite chimney (10 cm high).
1410	400	180	Approximately 70-80 m south of Marker #1. Still on sedimented bottom but with a few more white patches visible through the thin cover of pelagic mud.
1412	400	180	Approximately 100 m south of Marker #1. Few white patches in sediments, but no obvious anhydrite mounds.
1413	400	180	End of dive. Lifting off bottom. Bearing to pinger is 270°, suggesting that buoy is located near the main mound area.

STATION NO.: 328

JAGO Dive NO.: 633

Date: July 12, 1999

Time: 09:15-13:22 GMT

Depth Range: 404 to 381 m

Pilot: Jürgen Schauer

Observer: Peter Herzig

LOCATION: Central Grimsey Vent Field

Target Area: Active chimney cluster at the top of the 380m (anhydrite?) mound

Objective: Relocate the chimney cluster in the shallowest central part of the Grimsey vent field and sample high-temperature vents for fluids and gases. The active vents in the main part of the field were located during diving in 1997 and were not sampled. This dive was intended to locate and sample the highest temperature vents.

Summary:

JAGO descended at 9:15 at 66°36.41', 17°38.98' and landed at a water depth of 403m (seafloor) at 10:00 southeast of the boje, approximately 200 m east of the target area. After a short transit to the west over sediment-covered seafloor with no anhydrite outcrops, the first anhydrite boulders and crusts were located at the eastern slope of the 380m mound feature. Towards the top of the mound the area is littered with blocks of anhydrite, anhydrite crusts, small active chimneys (about 10-20cm) and larger areas of shimmering water. Some of the small chimneys are surrounded by reddish-brown halos of either bacteria or oxidized sulfides. With a heading of 270°, the slope is quite steep (about 45°) and many of the anhydrite blocks and boulders appear to originate from larger outcrops at the top of the mound. It appears as if the entire 380m mound consists of anhydrite and is thermally active. At the top of the mound, a larger active anhydrite field was located (but not sampled) at a water depth of 381m. The active areas are heavily populated with colorless shrimps. After a short transit to the southwest (heading 200°) an active beehive (about 1.5m high) was located at the eastern edge of the mound at 387m water depth. Close to this location, two smaller active chimneys (about 50cm high) were selected for sampling at 388m. The smaller of both was boiling showing the typical "flame" while the other vent was more diffuse along a crack on top of the chimney feature. After Marker II was dropped, a gas sample was taken close the the active chimney. The gas bubbles were emerging from the sediment and collected with the funnel. Before fluid sampling, one of the chimneys was knocked down with the arm. A temperature measurement at the newly created outlet gave a fluid temperature of 250°C, the other chimney had a fluid temperature of 248°C. The knocked down tip of the chimney was collected as sample PO 328. All fluid samples (P1-6) and the Niskin bottle were filled with the same 250° fluid at that particular vent. Also the ionic exchange column was flushed with the same fluid. In a few meters distance the "microbiology sock" was dropped in a suitable area covered with bacteria. Measurements of the seafloor sediment indicated temperatures of 50°C at the surface, 105° at 2 cm depth, and 150°C at 10 cm depth (full length of the temperature probe), confirming that the entire mound is indeed thermally active. The last part of the dive was used to explore the area southwest of the 380m mound (heading 250°), indicating sediment-covered terrain with a depression of >400m depth just west of the mound. Jago ascended from the seafloor at 399m at 12:45 and arrived at the surface at 66°36.21', 17°39.44' at 13:22.

DIVE LOG:

Time	Depth	Heading	Comments
0915	-	-	JAGO in water and being pulled toward boje.
0925	-	-	JAGO released at 66°36.413', 17°38.982'
0945	404	310	On bottom. Free water. Turning to 310° toward pinger.
1000	403	270	Bottom appears. Sedimented area with few shrimps – no anhydrite. Heading 270° towards 380m mound. First occurrence of anhydrite blocks, crusts, and small active chimneys. Some small depressions (2-3m). Shimmering water.
1025	384	270	Heading up 45° slope which is littered with anhydrite blocks and boulders.
1028	381	270	Shimmering water. Active anhydrite vent. Abundant shrimps. Entire area appears to be hydrothermally active.
1040	390	225	Active beehive in sedimented terrain.
1043	387	225	Two small active chimneys located. Dropped Marker II.
1105	387		Gas sample collected (gas emerging fom the sediment)
1125	387		Larger chimney knocked down. Collected tip of chimney as sample PO 328
1135	387		Temperature measurement at new outlet: 250°C. Collected 6 fluid samples from the same vent and flushed ionic exchange column.
1200	387		Moved to a sedimented area covered with white bacteria matts about 5m away from the two chimneys. Temperature measurements: 50°C at surface, 105°C at 2 cm depth, 150°C at 10 cm depth. Placed bacterial trap (sock) and covered it with some sediment.
1220	387		Returned to the two chimneys and filled Niskin bottle.
1230	399	250	Explored area to the west of the top of the 380m mound. Descend to a depression on the eastern slope.
1245	399		End of dive. Lifting off bottom.
1322			Arrive at the surface at 66°36.209', 17°39.437'.

rget LRT-BE4.V3

STATION NO.: 366

JAGO Dive NO.: 634

Date: July 17, 1999

Time: 08:15-10:04 GMT

Depth Range: 58 m to 88,5 m

Pilot: Jürgen Schauer

Observer: Jan Scholten

LOCATION: Tjoernes Peninsula

Target Area: Top hill area
Objective: Identify nature and structure of the surface in the Tjornes peninsula area;
Summary:

JAGO descended at 66°26.89', 17°10.32' and landed at a water depth of 58m (seafloor). The seafloor was a plane volcanic face with no sediment cover. The area was covered with little sessile benthos. Heading towards the east water depth gradually increased: The volcanic structure seems to have originated from several lava flows (striking SW-NE). Heading to the east, the flat volcanic platforms are followed by collapse structures. Small fissures crosscut the platform. Heading towards the steeper slope, talus (boulder size) of volcanic rock occurred. With increasing water depth (from about 68m) the amount of sediment covering the surface increased and the amount ofsessile benthos decreased. From about 83m depth ripple marks up to 40 cm high (striking north-south) were observed consisting of volcanic ashes and lapilli. The ripple marks on top of the volcanic subsurface are probably the cause for the diffusive echosounding record on top of a strong reflector. Talus fields intercalate with sediments and plane face of volcanic lava.

DIVE LOG:

Time	Depth	Heading	Comments
0818	-	-	JAGO in water and being pulled away from the ship.
0833	-	-	JAGO released at 66°26.899', 17°10.323'
0845	58	200	On bottom. Surface covered with volcanic rocks; benthos
0850	61	180	Plane surface of volcanic origin; fissures striking east-west; with sessile benthos increasing with depth
0900	63	90	Volcanic plane changing to talus field, which is probably a collapse structure. Layering of lava flows
0902	78m	100	Increasing amount of sediments, ripple marks;
0917	83m	90	ripple marks up to 20cm high, sediment is getting darker; in the valley of the ripples lighter sediments.
0925	86		Ripple marks up to 40 cm high, relatively coarse sediments

0940	87	110	Increasing amounts of talus.
0941	87,8		Surface consists of volcanic boulders.
0950	88	90	Plane volcanic face with thin sediment cover and sessile benthos
0955	88,5		End of dive. Lifting off bottom.
1005			Arrive at the surface at 66°27.142', 17°09.085'.

STATION NO.: 367

JAGO Dive NO. 635

Date: July 17, 1999

Time: 14:43 – 18:14 GMT

Depth Range: 400 to 394 m

Pilot: Jürgen Schauer

Observer: Viggo Thor Marteinsson

LOCATION: Grimsey Vent Field

Target Area: Southern Grimsey Vent Field

Objective: To find and collect bacterial trap which was placed on dive 632. Take some sediment samples from that area and place two new bacterial traps on the same diffusing vent. To collect hot water samples and chimney pieces from an chimney complex located above the bacterial traps.

Summary:

JAGO reached the seafloor at 400 m depth. We had drifted approximately 300 m south of the buoy. After we found the pinger which was very well placed by the RF Poseidon team, we detected our vent field approximately 50 m from the pinger. Our target area was the same as in Dive 632.

No typical vent macrofauna was observed and mainly shrimps of different sizes were present. White patches of bacteria filaments (Beggiatoa-like) were observed around shimmering water and active chimneys. This suggest that fluids contain sulfur or sulfur componds.

We found the bacterial trap where it had been placed on dive 632 and we deployed marker # 3 at this site. The current was strong. The bacterial trap was partly covered with white bacterial filaments (Beggiatoa-like). The surface temperature under the trap was mesured 55°C and 81°C at 1 cm depth in the sediment. After collecting the bacterial trap and 3 cups of sediment from this spot, we deployed two new bacterial traps (# 8 and 9). One small piece of rock was collected from the sediment area.

Water and rock samples were collected from an active chimney complex resempling to candelsticks. Some very hot fluid was collected into P1, P2 and P3. A gradient of hot water was collected into P4, P5 and P6. Hot water mixted with cold sea-water was sampled into Niskin bottle. Similar water was filltrated for 5 minutes. Two small active chimney pieces were collected.

DIVE LOG:

Time	Depth	Heading	Comments
14:43	0		JAGO is on the surface of the sea close to the buoy.
14:49	0		We start to dive. We have drifted away from the buoy. The sea temperature is 8.7°C
14:54	50		The sea temperature is 5.3°C
15:03	200		The sea temperature is 4.8°C
15:10	300		The sea temperature is 3.6°C
15:17	350		The sea temperature is 1.7°C
15:25	400		We have reached the seafloor, depth is 400 m and the sea temperature is 1°C. The submersible landed on a relatively flat and heavily sedimented bottom, approximately 300 m from the buoy position. We are heading north, towards the pinger.
15:30	395		We are observing an area of diffusive venting. The area is about 1 m^2 with shimmering water comming up. White patches of bacteria (Beggiatoa-like) are located around the diffusing fluids.
15:36	392.6	40	We have found the pinger at 392.6m depth about 300 m north of the place where we reach the bottom. We are heading 40° to find the spot where bacterial trap was deployed on dive 632.
15:44	398	40	We are heading up a gentle slope of large anhydrite mound. Anhydrite fragments are located in the sediment.
15:50	395	40	We have detected the bacterial trap (yellow ring as flotter) about 10-20 m in front of us.
15:51	395		We have reached the diffusing vent with the bacterial trap. Video and photo documentation. Half of the trap is covered with white filamentous bacteria (Beggiatoa-like), the other half is not covered with filaments. This spot is located on a slope of a large anhydrite mount at 395 m depth. About 3-4 m from an active chimney complex (Marker # 1). White patches occur on the edge around shimmering water. The area is about 70-80 cm^2
16:05	395	40	Marker # 3 deployed on the site.
16:10	395	40	We try to measure the temperature. The seafloor current is too strong for JAGO
16:14	395	40	We are going to the other side of the diffusing vent (marker # 3) to do some temperature measurements.
16:25	395	40	We are located on the other site and JAGO is sitting on the bottum. Temperature is mesured 60°C at approx. 10 cm depth on the edge of the shimmering water area. The temperature probe can't reach the main diffusing area. We nedd to go approx. 30 cm closer.

16:27	395	40	We have reached closer. Jürgen managed to do this by „rocking" the submersible towards the target. Temperature is mesured 107°C at approx. 10 cm depth and around 10 cm from the bacterial trap. We need to go additional 15 cm by „ rocking" JAGO on the seafloor.
16:30	395	40	We are on the right spot for working. Temperature is mesured 32°C at the tip of the bacterial trap on the sediment surface. At approx. 1 cm depth the temperature is mesured 81°C.
16:34	395	40	The bacterial trap has been retrived and a temperature of 55°C is measured on the surface where the trap was placed.
16:39	395	40	Two new bacterial traps (# 8 and 9) placed on the bottom.
16:40	395	40	We are taking sediment samples at the spot where the bacterial trap was placed.
16:42	395	40	The first cup of sediment sample is in the basket tube
16:43	395	40	The second cup
16:45	395	40	The third cup
16:48	395	40	The bacterial trap from dive 632 has been placed inside the basket tube.
16:50	395	40	The arm of JAGO is scraping the sediment before deploying the two new bacterial traps (# 8 and 9).
16:53	395	40	The trap # 9 is on place.
16:55		40	The tap # 8 is on place
16:58	395	40	The temperature probe is in the baskete tube and we can close the lid.
16:59	395	40	Video and photo documentation.
17:00	395	40	We collect one piece of rock with some shining spots on it. It seems that the rock appeared after the sediment sampling.
17:04	395		We are heading for a chimney complex few meters to the right site of JAGO. The seafloor current has decreased.
17:08			There are yellow patches (oxidation of anhydrite) on our way to the chimney complex.
17:10	394		We are at the chimney complex.
17:15	394		Video and photo documentation. The chimney complex (candelsticks) consist of 3 high anhydrite spires (1-2 m) which seems to be none active and two smaller active chimneys (approx. 5-10 cm) with high temperature outlets (temperature was mesured 251°C in dive 632). The chimney complex area is approx. 3-4 m in diameter.
17:20	394		We are using the manupulator of JAGO to brake some chimney pieces without any success. The two small chimneys seems to be made of some hard „stuff".
17:21	394		We manage to brake the tip of the left small chimney which fell down in front of us.
17:25	394		We are taking water samples for P1, P2 and P3. The end of the tube is placed in the middle of high-temperature outlet (measured 251°C on dive 632).
17:30	394		Valves # 1, 2, and 3 are closed.
17:31	394		We are taking water for P4, P5 and P6. The end of the tube is placed approx. 3 cm above and from the middle of the hot fluid outlet (gradient water).
17:37	394		Valves # 6, 5 and 4 are closed.
17:38	394		We are collecting the tip of the chimney (broken at 17:21) into the

		basket.
17:42	394	We start pumping and we are collecting water from diffused flow, about 10 cm above the vent outlet.
17:47	394	We stopp pumping (pumping time was 5 min)
17:48	394	A small diffusing chimney piece (irregular shape, 15 x 20 cm) on our left site has broken lose. We collect it into the basket.
17:49	394	We collect water (10 – 20°C) about 20 cm above diffusing water, into Niskin bottle.
17:50	394	We have been asked to leave the seafloor because of a bad weather conditions on the surface.
17:50	394	End of dive 635
18:14	0	We are on the surface.
18:25		The submersible JAGO is on board of RF Poseidon.

STATION NO.: 380

JAGO Dive NO. 636

Date: July 19, 1999

Time: 09:00 – 12:50 GMT

Depth Range: 377 to 398 m

Pilot: Jürgen Schauer

Observer: Mark Schmidt

LOCATION: Grimsey Vent Field

Target Area: Southern Grimsey Vent Field

Objective: To find new hydrothermal fluid outflows in the southern area of the vent field. To collect hot water and gas samples in a chimneys outflow, sampling parts of a chimney and looking for sulfide bearing rocks.

Summary:

Dive 636 started at sea surface (66°36,368N / 017°39,648W). JAGO reached the seafloor at 393m depth, west of the southern hydrothermal vent area.
We headed south-east to the vent area and reached it after 20min. During this period we collected a 20cm red rock lying on the sediment surface. The rock was covered with algae and two small anemones and probably consists mainly of pyrite.
When we reached the southern vent field we approached a 3m high active chimney. White patches of bacteria filaments have covered the chimney.
Heading further south we discovered a second large and very active anhydrite chimney. The gas and water sampling was done near the last mentioned chimney.

DIVE LOG:

Time	Depth	Heading	Comments
09:00	0		JAGO started diving at 66°36,368N / 017°39,648W

09:32	393		We reached the sediment covered sea floor (water temperature=0,5°C). Shrimps and one flat-fish were observed; ripple marks (appr. 3cm, height)
09:33	390	100	Heading east, reaching a slightly ascending area covered with sediment and small pieces of anhydrite. One sneel and several starfishes and anemones were observed.
09:46	388	0	Heading up a slope north. Shimmering water at small patches. Yellow-brownish sediment.
09:49	386	0	Collecting a 20cm red rock sample lying on the sediment surface. The sea temperature is 0.6°C
09:54	382		Reaching the top of the hill. Approaching a 3m x 1,5m vent block with several small outlets with shimmering water. The chimney is covered with white and green-brownish bacterial mats.
10:13	385	200	Heading south down the small hill.
10:23	398	240	Heading up south-west. Water temperature 0,4°C.
10:33	385	250	Small pieces of anhydrite and small patches of shimmering water.
10:36	380		Sampling gas at a small sedimentary gas outlet beside an anhydrite rock.
10:46	380		Stop sampling gas with glass bottle sampler (Schmitt designed). Marker #4 was deposited at gas sampling area.
10:51	380	260	Going uphill.
10:54	378		Reaching a large and active anhydrite chimney (2m x 1m). Further north a steep descending slope can be observed. One calamar and several red perches are observed. Water temperature above the chimney is 2,5°C.
11:15	378		Sampling hot fluids with the Gradient Sampler (Garbe-Schönberg designed). P5+P6 and P3+P4 and P1+P2 are used for the same sample position.
11:34	378		Niskin-bottle was closed in the hot fluids. A small sidearm chimney (20cm long) is sampled. After sampling we turn around with JAGO and hit the chimney
12:03	379		Hot fluids (249°C) are coming out of the new opening (base of smashed chimney). Hot fluids were sampled over 5 min trough a filter system (J. Scholten designed) for radiochemical investigations.
12:03	379		End of dive 636
12:35	0		JAGO is back on the sea surface (66°36,230N / 017°39,316W)
12:50			JAGO is on board POSEIDON

STATION No.:	382
JAGO Dive NO.:	637
DATE:	19.07.1999
TIME:	16:45 – 20:45
DEPTH RANGE:	377 – 399m
PILOT:	Jürgen Schauer
OBSERVER:	Heike Preißler
LOCATION:	Grimsey Island
TARGET AREA:	Southern ridge segment of the Southern Grimsey Vent Field
OBJECTIVE:	Locating and documentation of hydrothermal vent sites
SUMMARY:	Four anhydrite mounds were found on top of the southern ridge. Three have chimneys on top and flanks (consisting mainly of anhydrite walls and talc lined interiors) with venting hot shimmering clear fluids. Boiling was not observed. Hydrothermal fluids were sampled from two vents (measured temperature: 248°C). Gas bubbles were sampled in sediment directly beside base of mound #4, because fluids were without or poor in bubbles. One anhydrite mound (#3) was either completely sealed off or already inactive (no fluids, no vents). Furthermore, an extinct vent site (3x3m) could be located. Two interesting samples (anhydrite remnants) were recovered from this area. Relatively low fluid flux rates, completely and nearly completely sealed off mounds, and the extinct vent site are indications for a recent waning stage of hydrothermal activity on the southern ridge of Southern Grimsey Vent Field.
SAMPLES TAKEN:	1 active anhydrite vent (PO 382-3) 2 haematitic mudstones (PO 382-4) 2 slabs of residual anhydrite, siliceous sinter (PO 382-1, PO 382-2) 1 gas sample 7 water samples

Time	Depth (m)	Comments
1645		Towed from bord
1653		Submerged, many shrimp in lights
1724	388	Landed northwest of the southern ridge from Southern Grimsey Vent Field (17°39.1W, 66°36.30N), moving briefly to north-east, then change of course to south-east, bottom is flat and sedimented with normal tan-coloured pelagic sediment

1728	388	Sporadically anhydrite chimney fragments (ca. 20 to 30cm in length) in sediment on the north-estern ridge flank
1730	385	Slope up the ridge on the north-eastern edge, fractures in sediment are emanating clear shimmering water; around the fissures white patches of bacteria mats
1733	382	Coming to edge of anhydrite mound #1 (approximately 6m in diameter at base, 3m high, 35° slope on sides of the mound) on top of the ridge, the mound is nearly completely sealed off, just one small active vent (ca. 20cm in high) eminates clear hot fluids
17:45	384	Heading south on the eastern ridge flank following white bacterial mats
17:52	383.5	The heavily sedimented, flat bottom shows rippled marks, probably leaving by fishing nets
17:53	383.5	Several fragments of broken down, inactive anhydrite chimneys are lying on and are covered slightly by sediment, several anemones are "in bloom" on it, no fluid exits on this flank site
17:54	384	White patches of bacteria and numerous older anhydrite fragments cover the bottom
17:55	381	Slope up the ridge at 17°39.20'W, 66°36.25'N again, reaching the nearly top, a second anhydrite mound #2 (diameter at base ca. 4m) emanating clear fluids out of two small vents (ca. 20 to 30cm high) is found
17:56	378	Another mound #3 (diameter at base ca. 4m) consisting mainly of anhydrite is located ca. 5m southwards; no fluids could be observed, no vents on the top; vents are totally sealed off or already inactiv ->
18:00	377	Few metres away the fourth anhydrite mound #4 (ca. 5m in diameter at base) on this rift segment was detected on top of the mound a very nice (see video movie) active, beehive-structured vent (ca. 2m in high, diameter at base ca. 70cm) with ribs around chimney; the vent structure consists of anhydrite and patches of black stuff (disseminated sulfides?) on the outside and is overgrown by white bacteria mats; no other vent specific animals are seen (same for the other mounds); clear shimmering fluids are emanating out of the single vent orifice (15cm) and numerous small cavities of the chimney wall and the base (well video-recorded); this is the most intensive fluid flux observed on this ridge; another smaller vent (25cm in high) emanting clear shimmering fluids as well, is located on a flank of the anhydrite mound
18:25	377	The attempt to sample the beehive vent was depraved because of expected technical difficulties during recovering due to big size and weight of the chimney and the hot temperature of vent fluids
18:34	377	Successfull recovering of small active vent (sample PO 382-3) from the mound flank
18:35	377	Positioning of equipment for water sampling in the main upflow of the knocked-over vent, two samples are collected directly in the residual vent orifice, two sampls 2cm above it, and another two samples from 5cm above orifice
18:51	377	Some gas bubbles were coming out on the mound flank adjacent to the location of the recovered vent, but sampling was interrupted because of too small amounts of emanating gas

19:00	380	Observation of lots of gas bubbles coming out of a small anhydrite orifice (2cm high, diameter ca. 5cm) stacking in sediment at the base of anhydrite mound #4, sampling gas bubbles
19:25	380	End of gas sampling
19:27	377	Return to mound #2, start water sampling of fluids emanating out of a small vent (15cm high, exterior: anhydrite, interior: talc) in Niskin bottle, sample was sucked in directly from vent orifice
19:30	377	End of water sampling, measurement of temperature: T=248°C
19:43	395	Continuing heading south, sedimented bottom with local bioturbation
19:44	395	Several anhydrite chimney fragments (talus) are loose scattered in sediment
19:46	397	Red roundly-shaped stones (sample PO 382-4) are observed and sampled on sediment
19:55	397	Sligthly hilly sedimented area (ca. 3x3m) scattered with few relatively large (up to 60cm) brown, black and reddish-coloured old fragments of anhydrite chimneys (relicts of an extinct vent site), recovering of two samples (PO 382-1, PO 382-2), red tails
20:10	397	End of dive
20:45		JAGO on deck

STATION NO.: 386

JAGO Dive NO. 638

Date: July 20, 1999

Time: 13:30 – 17:10 GMT

Depth Range: 381 to 405 m

Pilot: Jürgen Schauer

Observer: Jan Scholten

LOCATION: Grimsey Vent Field

Target Area: Central Grimsey Vent Field

Objective: To investigate the connection between northern (investigated during Poseidon cruise 229) and central Grimsey hydrothermal fields. Sampling of fluids and gas, recovery of bacteria traps and hydrothermal precipitates.

Summary:

Dive 638 descended at 66°36,41N / 017°39,44W and JAGO reached the seafloor at 386m in the western part of the central hydrothermal vent area. The surface was covered with sediments containing some white patches of beggiatoa. Heading 60° uphill rubble of anhydride was observed frequently and at the top of the mound (382m) four anhydride chimneys surrounded by collapsed chimneys occurred. Vent fluids showed two-phase-fluids indicating that the water was boiling. Marker VI was dropped at the top of the mound and at the base of the chimneys a gasoutlet characterised by relatively big bubbles was sampled for gas. Heading 60° downhill a structure in the surface sediment with the contours of the bottom weight of the buoy (probably buoy of dive PO367) was observed. Heading about 330° uphill a piece of red rubble was observed probably composed of hematite. At the top of the mound (381m) shimmering water and several small chimneys with boiling vent fluids occurred. Heading 30° downslope bottom contact was lost. In 389m the bottom was sediment-covered with several small holes. Heading upslope rubble of anhydride was observed and at the top of the mound (387m) several chimneys occurred surrounded by anhydride rubble. From a fracture at the base of the chimneys shimmering water escaped. A whitish piece of a chimney was collected. The dive continued in the direction of 30° downhill. After a plane area, again a mound occurred. Markers I and III were found (394m) at the vent field at the top of the mound which had previously been deployed at this site during dives PO323 and PO382. Two bacteria traps dropped during these previous dives and marker III were re-collected. Heading 46° downhill at 403m depth sediments with ripple marks occurred. At 405m depth a continuation of the diving was not possible due to the increasing water depth and diving continued in the direction of 230°. Again the vent field marked with marker I was found. Sampling of diffusive vent fluids was not possible due to the high amounts of suspended particles which were mobilised due to the manoeuvring of JAGO. An active anhydride chimney was sampled and at this outflow the vent fluids were collected.

DIVE LOG:

Time	Depth	Heading	Comments
13:30	0		Descending at 66°36,409N, 17°39,438 W
13:40	100		Drifting to the west; JAGO started heading east
13:48	270	100	According to the subpositioning system location of JAGO is now in the centre of the Grimsey Field
13:55	386		Gas bubbles and bottom sight; white patches of bacteria; heading 60°
13:56	383	60	Talus composed of anhydride sometimes with white and grey laminations; in the centre of talus field four active chimneys with active venting and phase separation (boiling); marker IV dropped; at the base of the chimney shimmering water and many tiny gas bubbles
14:16	382		Relatively big gas bubbles were sampled at an outlet at the foot of the chimneys; sampling period of about 5 min; about 200ml
14:30	383	60	Heading downhill
14:32	386	44	Bottom contact lost
14:33	388		Bottom covered with sediments; still heading downhill
14:34	390	63	Plane face covered with sediments followed by a gentle slope with patches of white bacteria and shimmering water; some anhydride rubble; plat fish and abundant big shrimps
14:35	388		Heading downhill again; impact mark in the sediment with the contours of the buoy weight deployed for dive PO367
14:44	390	330	Heading uphill; a piece of baked mud was sampled with the manipulator but not recovered
14:50	381	330	At top of the mound anhydride rubble with shimmering water followed by a small depression in which small (30cm in height) active chimneys are located; fluids venting from the chimneys show indications of phase separation (boiling); continuing the dive heading 30° downhill; loss of bottom sight.
14:52	389	30	Sediments with white patches of bacteria and anemones
14:55	387	30	Heading upslope again; at the top of the mound anhydride rubble and in the centre active chimneys with vents showing phase

			separation (boiling). At the base of the active chimney shimmering water emerges from a fissure of about 1,5 m in length. An active chimney is broken and a fresh piece of the chimney (whitish at the inside) is sampled. Dive continues heading 30° downslope
15:10	398	30	Plain area with striation marks in the sediments (probably from fishing activities).
15:11	398	30	Heading uphillslope; at the top of the mound vent field and marker I and III observed; two bacteria traps and marker III recovered; during recovery remobilization of sediments and only little visibility; from the second trap shimmering water emerged when recovered
15:35	397	46	Continuing dive downhill
15:40	402	345	Small hill; sediments show ripple marks
15:45	403	50	Small holes in the sediment
15:46	405	230	Changing of diving direction due to the increasing water depth
15:50	402	230	Anhydride rubble; gentle uphill; temperature in JAGO 4°C; 50% humidity;
16:10	394	395	At the vent field marked with marker I; looking for a location to sample diffusive vent flow; search was stopped due to the high amounts of resuspended sediments; small active chimney collected and fluid sampling was undertaken at the vent orifice; no niskin sample (broken rope).
16:30	394		End of sampling; lifting off the bottom
16:35	388		switch on the pump for radio-tracers (sampling of ambient bottom water)
16:41	280		End of pumping
17.00	0		At the surface

Sample descriptions

1. JAGO Dives

PO 323 (active anhydrite vent)

Samples consist almost of anhydrite and are coated by some talc. Fine black tiny crystals (pyrite?) are dispersed in some of the samples.

PO 323-1	mixture of pelagic ooze and anhydrite/gypsum sand
PO 323-2	anhydrite crust (may be some gypsum). Looks as though it grew as individual lobes that coalesced into a plate. Anhydrite is plated to fibrous, as well as networks of subhedral (rhombs) grains. Exterior is dense. Interior surface is coated with 0.2 to 0.5 mm zoned botryoidal layers of pale brown talc (?) overlying similar layers of pale yellow talc (?). Interlobe "veins" also consist of talc-like material that is botryoidal, up to 0.5 cm thick, and has a darker mid-brown to purplish colour.
PO 323-2A	Very friable and soft pale brown talc botryoids (up to 0.5 mm diameter) from the interior of chimney.
PO 323-2B	Vein of purplish brown talc within the anhydrite. It is much harder than the surface layer (indurated?) and of similar morphology.
PO 323-3	Very porous anhydrite that looks to be part of a fluid channelway although collected as a crust or low mound. Anhydrite has grown as 1 to 3 cm radial sprays of soft bladed forms. These knobs are coated with 0.1 to 0.3 cm thick pale brown talc (?). Fibrous anhydrite knobs enclose irregular patches of pale grey impregnations and veinlets. Probably these are sulfidic although they do not line channelways.
PO 323-3A	Inner chimney surface coatings of talc.
PO 323 – 4	Crusty, massive anhydrite with knobby structure. Its interior is coated with 0.1 to 0.3 mm pale brown talc (?) botryoids that overlie paler buff-white botryoidal talc (?). The same buff-white talc forms inner sutures between white anhydrite knobs/lobes. Some cm wide white anhydrite veins cut across the specimen.
PO 323 - 4A	Pale brown talc from the interior of anhydrite.
PO 323 - 4B	Buff white talc "veins" from the interior of chimney.
PO 323 - 4C	Small scale worm that crawled out of interstices of anhydrite. These worms also are commonly seen in weathered basalts and indurated bio-burrowed muds collected from dredge hauls.
PO 323 – 5	Sample collected as an active chimney top is nearly cylindrical (tapered up) and displays distinctive layering around a single 2 to 2.5 cm conduit. Outer layer comprises 0.1 cm hard crust of near massive, but fibrous (sub-mm) anhydrite with numerous pore holes lined by grey-black (pyrite?) material. Entire exterior is smoky grey. Some break-out vents (ca. 1 cm) are lined with coarser bladed arrays of anhydrite. Inner layer is coated with thin lining of pyrite (?) (0.2 mm) and is 1 to 3 cm thick. It consists of outwardly splayed white fibrous anhydrite, a hard exterior, and is progressively softer and more friable inwards. Conduit is roughly elliptical - innermost surface layer is harder anhydrite that is stained pale yellow (talc?).
PO 323 – 6	Multichanneled anhydrite chimney top, effectively a coalescence of two major channels with numerous small side channels. very friable. Outer layer consists of black to grey impregnated (pyrite?) white anhydrite. Inner layer consists of

acicular spheroids of finely crystalized anhydrite. Knobs are intergrown 0.2 to 2 cm diameter, radiating crystallites are needles up to 0.1 mm long.

PO 323 – 7 A very porous chimney top consisting of bladed arrays of anhydrite that form hemispheroidal knobs and nodes. These are coalesced to leave cm-sized voids stained pale yellow. Void spaces are around 20% and act as fluid conduits. Exterior is harder anhydrite, pocked and stained with grey-black pyrite (?). Sample broke on recovery but it comprases about half of the original top.

PO 328

PO 367 (active anhydrite vent)

A ca. 250°C vent was collected. Numerous small spigots were venting through a soft anhydrite + black coatings (pyrolized bacteria? +pyrite?) on the walls of chimney - sideways.The main 10cm wide fluid channel (boiling flame) is enclosed in white hard anhydrite and lined by pinkish-brown botryoidal talc, 1 to 3mm thick. The first lines of "black" inwards from the central vent wall also mark the point of return to soft friable (presumably very porous) anhydrite. These mark zones of coalescence of former exterior surfaces on individual spigots, now forming the outer composite wall to the main vent. This is seen in detail in the large cross-section of the chimney, where 6 to 9 inner talc-lined conduits core the subspheroidal structures whose outer limits are black rimmed. Inspection of the section across the side spigots shows that while the very outer tips are lined by soft white anhydrite, at depths of no more than1cm into the spigot, the first signs of talc colouration on linings (pale pink or yellow) become visible.

PO 380 (weathered conduit infill, active anhydrite vent)

PO 380-1 One 1kg piece of rusty, strongly weathered pyrite-anhydrite conduit infill (now gypsum, rust and about 80% peserved), clearly quite old. Texturally fine pyrite surrounds mm "anhydrite" grains and may have replaced these to form near massive pyrite in the walls. Fluid pathways are lined by botryoidal hard pyrite. The observation of other rusty lumps in the area (flat) suggest that this is now an inactive site and these are aged remnants from a sulfate mound long since dissolved away.

PO 380-2 Two anhydrite chimney tops, each with cm-sized multiple spigots lightly lined with talc. Each was blocky in shape with spindles.

PO 382 (inactive anhydrite mound, active anhydrite chimney)

Samples recovered from an old denuded hydrothermal mound area, represent relicts of fluid channelways, anhydrite custs, mud, sulfidic sinter, and siliceous sinter. All are presumed (inferred) to have been formed near to the original seafloor surface that underlay the mound, now largely dissolved away. It may be possible to date residual crusts radiogenically.

PO 382-1 An irregular slab of residual anhydrite (now partly gypsum) surface crust. Its appearance suggests it was the root to a chimney or upflow conduit, being concave upwards with a vertical channel feeding out of it (ca. 8cm across). The underlying cavity is composed partly of altered indurated mudstone and sinter-like silica layers and seems to have been part of a lateral fluid channel.

PO 382-2 This is a conforted siliceous finely layered sinter that now encloseds a red ockre, perhaps formerly a pyritic sulfide pod. It has interlayers of residual anhydrite. It is quite porous and has a sandy texture. Finely bedded laminae are conforted and imply slumping or differential compaction due to original mix of silica, sulfate, sulfide, mud, etc. The red portions are also largely siliceous, but still soft and friable.

PO 382-3 Classical example of a hot spring anhydrite (now gypsum) breccia sinter where fragments are cemented strongly by 0.5 to 1.0mm black quartz (?) veinlets forming a tight network. A central zone of sulfate fragments remains soft, but above and below more massive layers are silicified and look weakly recrystallized

PO 382-4 Two pieces of reddish hematitic very soft brick-like material bearing <1% disseminate basalt glass grains. Looks to be an indurated mud from which silica has been removed and replaced by iron hydrolysates. Reminiscent of hydrothermal vent ochres, but not yet (re)silicified.

PO 382-5 Brown mudbrick of surface bioturbated material. Perhaps a residue of hydrothermal baked sediment from within the former mound.

PO 382-6 Small anhydrite-sulfide chimneys, broken up. Active coated with bacteria matter and their pyrolyzed remains. Iron sulfides?

PO 386 (active anhydrite chimney)

PO 386-1 Two pieces from a large active chimney cored by thick cauliflower textured white talc up to 4cm thick. Essentially botryoidal in habit, interior surface. Exterior is a thin coating of anhydrite crystals and minor pyrite grains plus bacterial pyrolyzates.

PO 386-2 Chimney top with multiple spigots coated in black bacterial matte and coloured inside by talc, but only at its base. Top spigots are barely stained yellow.

Macroscopic Sample Description of the East Grimsey Vent Field, Kolbeinsey Ridge, Iceland (Cruise POS-253)

Station	Sample	Description	Size and Weight	Distribution
323	PO 323	Samples consist almost of anhydrite and smell faintly of hydrogen sulfide. Anhydriteis coated by some talk. Fine black tiny crystals (pyrite?) are dispersed in some of the samples.		
	PO 323-1	Mixture of pelagic ooze and anhydrite/gypsum sand. Typical areal bottom sediment, i.e., pelagic ooze covering sand; fine mud is brown to green-brown, mostly mm to submm sand size.	ca. 0.5kg	GSC, TUBAF
	PO 323-2	Anhydrite crust (may be some gypsum). Looks as though it grew as individual lobes that coalesced into a plate. Anhydrite is plated to fibrous, as well as networks of subhedral (rhombs) grains. Exterior is dense. Interior surface is coated with 0.2 to 0.5 mm zoned botryoidal layers of pale brown talc (?) overlying similar layers of pale yellow talc (?). Interlobe „veins" also consist of talc-like material that is botryoidal and up to 0.5 cm thick. It is a darker mid-brown (purplish).	15x10x6cm, 1kg	GSC, TUBAF
	PO 323-2A	Very friable and soft pale brown talc from the interior of chimney. Individual botryoids may be up to 0.5 mm diameter.It was subsampled into a small vial for identification and □18O studies.		to GSC for purification of talc (□18O), return to TUBAF later
	PO 323-2B	Vein of purplish brown talc within the anhydrite. It is much harder than the surface layer (indurated?) and of similar morphology. It was subsampled for identification and oxygen isotope studies.		to GSC for purification of talc (□^{18}O), return to TUBAF later
	PO 323-3	Very porous anhydrite that looks to be part of a fluid channelway although collected as a crust or low mound. Anhydrite has grown as 1 to 3 cm radial sprays of soft bladed forms. These knobs are coated with pale brown talc (?), 0.1 to 0.3 cm thick. Fibrous anhydrite knobs enclose irregular patches of pale grey impregnations and veinlets. Probably these are sulfidic although they do not line channelways.	13x10x8cm, 1kg	GSC, TUBAF
	PO 323-3A	are inner surface coatings of talc, subsampled into a small vial.	100g	talc separate to GSC for purification
	PO 323 - 4	Largest piece of crusty, massive anhydrite and knobby in structure (cf 2). Its interior is coated with 0.1 to 0.3 mm pale brown talc (?) botryoids that overlie paler buff-white botryoidal talc (?). The same buff-white talc also forms inner sutures between white anhydrite knobs/lobes. Some cm wide white anhydrite veins cut across the specimen.	20x10x8 cm, 1.5 kg	GSC, TUBAF
	PO 323 - 4A	Pale brown talc from the interior of anhydrite.	100g	
	PO 323 - 4B	Buff white talc „veins" from the interior of chimney.	100g	

	PO 323 - 4C	Small scale worm that crawled out of interstices of anhydrite. These worms also are commonly seen in weathered basalts and indurated bio-burrowed muds collected from dredge hauls.		
	PO 323 - 5	Collected as an active chimney top: Sample is near cylindrical (tapered up) and displays distinctive layering around a single 2 to 2.5 cm conduit. Outer layer comprises 0.1 cm hard crust of near massive, but fibrous (sub mm) anhydrite with numerous pore holes lined by grey-black (pyrite?) material. Entire exterior is smoky grey. Some break-out vents (ca. 1 cm) are lined with coarser bladed arrays of anhydrite. Inner layer is coated with thin lining of pyrite (?) (0.2 mm) and is 1 to 3 cm thick. It consists of outwardly splayed white fibrous anhydrite, hard exterior, progressively soft and friable inwards. Conduit is roughly elliptical - innermost surface layer is harder anhydrite that is stained pale yellow (talc?).	300g	GSC, TUBAF
	PO 323 - 6	Multichanneled anhydrite chimney top, effectively a coalescence of two major channels with numerous small side channels. very friable. Outer layer consists of black to grey impregnated white anhydrite looks like pyrite. Inner layer consists of acicular spheroids of finely crystalized anhydrite. Knobs are intergrown 0.2 to 2 cm diameter, radiating crystallites are needles up to 0.1 mm long.	6x6x6cm, 300g	GSC, TUBAF
	PO 323 - 7	Very porous chimney top consisting of bladed arrays of anhydrite that forms hemispheroidal knobs and nodes. These are coalesced to leave cm-sized voids stained pale yellow. Void spaces are around 20% and act as fluid conduits. Exterior is harder anhydrite pocked, and stained with grey-black pyrite (?). Sample broke on recovery but was roughly and looks like it comprases about half the original top.	5x3x3cm, 200 g	TUBAF
325	DR 325	glacial basalts, pale grey-green leicht verfestigte Tone with bioturbidation ofworms, seastars	6 pieces, together 1kg, 500g	TUBAF TUBAF
331	DR 331	verfestigte Toncrusts with Fe-oxides and lots of worms in channels basalts with oxidized crusts	several pieces, 1kg several pieces, 1kg	TUBAF TUBAF
335	GC 335	Dehydrated grey-green clay with fine-grained disseminated pyrite mineralization, lenth of core 160cm, 75°C in the core catcher	500g	TUBAF
336	DR 336	Tonsteine with Fe-oxides on surface and worm channels (0.4mm in diameter), glacial basalt, and basalt with Fe-oxides	1.5kg 2 pieces	TUBAF

		basalt with rind of relatively fresh glass	1 piece	
337	GC 337	Material in the core catcher (83°C) consists of gravel size (mm -> cm) grains of variably altered holocrystalline basalt mixed with fine grey mud. This could be hyaloc lastic material or turbiditic sediment. The whitest grains (should be mounted for PTS) are impregnated with minute pyrite flakes and stringers. Finer pyrite is dispersed in the muddy matrix. Crude crushing and panning recovered about 10g of pyrite concentrate. The efficiency of this process is probably no more than 25%. The finest pyrite floats is lost within uncrushed altered lava grains. Alteration minerals should be identified along with compositions of least altered grains (microprobe).	34 subsamples between 50 to 700g,	TUBAF
339	GC 339	The section is similar to GC 337, but less complex. 74°C wee measred in the core catcher (160cm)	15 subsamples 1 sample	TUBAF ICETEC
347	GC 347	This is a long section dominated by anhydrite debris flows and poorly developed prroximal turbidite profiles. Clearly, these formed in depressions on the side of slopes of hydrothermal mounds or ridges. The section can be subdivided into 3 or 4 discrete debris flows. Each shows evidence for coarse to finer upward deposition, typical for proximal turbidite and debris flows.	30 subsamples around 200 to 300g	TUBAF
352	GC 352	brown-green turbidite mud, 44°C in the core catcher	2 subsamples (top, base), 150g 150g	ICETEC TUBAF
357	DR 357	basalts with quartz crystals and stilbite (?) in small voids	7 pieces, largest 13x10x7cm, 3kg all together	TUBAF, GPI Uni Kiel
359	GC 359	green-brown mud, 2% basaltic glass (grit), trace pyrite, 25.8°C in core catcher	200g	TUBAF
360	GC 360	Core catcher and 40 cm of gravel sized, unconsolidated material consisting of an estimated 30 to 40% talc (botryoidal, pink to white) and 50 to 60% anhydrite (white). Some thin black (0.5 to 1cm) shards of an indurated layer consisting of pink talc, white hard anhydrite and some suspected quartz. There is also a green mineral present. This indurated layer cements indiscrete anhydrite grains to produce a hard conglomerate up to 5cm thick. It seems to enclose the black stained material. A few pieces of the gravel are reddened with iron oxide. There is no smell of H2S.	9 subsamples 2 pieces of the larger concretion	TUBAF, GSC

		The recovery yielded one bigger piece that was cu to expose about 40% botryoidal talc seemingly replacing bladed anhydrite. It is clearly cementing the material together. Mineralogical and microprobe work are required		
367	PO 367	A ca. 250°C was collected. Numerous small spigots were venting through a soft anhydrite + black coatings (pyrolized bacteria? +pyrite?) on the walls of chimney - sideways.The main 10cm wide fluid channel (boiling flame) is enclosed in white hard anhydrite and lined by pinkish-brown botryoidal talc, 1 to 3mm thick. The first lines of „black" inwards from the central vent wall also mark the point of return to soft friable (presumably very porous) anhydrite. These mark zones of coalescence of former exterior surfaces on individual spigots, now forming the outer composite wall to the main vent. This is seen in detail in the large cross-section of the chimney, where 6 to 9 inner talc-lined conduits core the subspheroidal structures whose outer limits are black rimmed. Inspection of the section across the side spigots shows that while the very outer tips are lined by soft white anhydrite, at depths of no more than1cm into the spigot, the first signs of talc colouration on linings (pale pink or yellow) become visible.	3 to 4kg large slice: 20x10x4cm, thinner slice: 20x10x2.5cm, side slice of anhydrite: 5x4x3cm, underlying section: 10x8x3cm, miscellaneous pieces and fragments, piece of talc-rich inner crust: 9x3x3cm, 2 thin shaves anhydrite + black material: 3x3x0.1cm, small tip of anhydrite chimney, regrown from dive #1	TUBAF GPI Uni Kiel GSC GSC TUBAF GPI Uni Kiel GSC GSC (for PTS)
369	GC 369	This 2.40m section is entirely within altered mud sequences. The prevasive, but low level clay alteration is controlled by anastomosing networks of fractures induced by baking and dehydration from a hydrothermal aquifer 2.5 to 3 metres below. Likely the spent hydrothermal fluids have reached to the present seafloor. No gelantinous ooze was recovered in this core. Top core temperature was measured at 63°C, bottom was 101°C. Mineralization in the form of pyrite veins is seen to occupy the cores of altered clay „veins" as discontinous veinlets, tiny vug infill, and dense disseminations.Clearly, the ground has been prepared to receive mineralizing fluids as dehydration and shrinkage continues. This core boiled on deck then recovered.	22 subsamples	TUBAF
370	GC 370	Core catcher: 100.6°C, top: 62.8°C, boiling, strong smell of H_2S, Core bit in an anhydite sand (+talc). Considerable free pyrite embedded in recrystalized anhydrite, as needles, blades, flakes, and tubular dendrites. Mud was altered to a pale blue-grey - seen previouscly to be	10 subsamples	TUBAF, GSC

		characteristic of high-temperature alteration of pelagic mud.		
371	GC 371	Core catcher ended in hardened warm (27°C) mud, little altered but dehydrated. A pan of the core ctacher material yielded about 1% basaltic glass, trace pyrite, and other darker heavies (mt?)	2 subsamples	1 x 402 vial TUBAF, heavy minerals, 1 x 402 vial GSC
372	GC 372	Core bit into a talc-mud gravel at about 100°C (boiling). Topped by mud. Gravel was dry (probably drained out). The rest was panned to yield pure talc sand and minor pyrite concentrates. Overall the gravel consisted of 80 to 90% talc (mm -> cm), 10 to 20% grey mud, <= 0.5% pyrite. Heavies seem to be pyrite + some rhombic crystals (barite?).	34 subsamples	TUBAF and GSC
373	GC 373	Green-brown mud.	2 subsamples	TUBAF and GSC
374	GC 374	This represents a long (3m) section of hemipelagic mud and imposed hydrothermal alteration on that material.		
375	DR 375	One basalt and one mudstone (pale brown with bioturbation).	2 small samples	TUBAF
380	PO 380-1	One 1kg piece of rusty, strongly weathered pyrite-anhydrite conduit infill (now gypsum, rust and about 80% peserved), clearly quite old. Texturally fine pyrite surrounds mm „anhydrite" grains and may have replaced these to form near massive pyrite in the walls. Fluid pathways are lined by botryoidal hard pyrite. The observation of other rusty lumps in the area (flat) suggest that this is now an inactive site and these are aged remnants from a sulfate mound long since dissolved away.	1kg	topslice with vents to TUBAF, midslice of best pyrite for dating to GPI Uni Kiel, basal pieces and chips to GSC
→ 381?	PO 380-2	Two anhydrite chimney tops, each with cm-sized multiple spigots lightly lined with talc. Each was blocky in shape with spindles.	20x10x5 18x11x5	TUBAF, GPI Uni Kiel
382	PO 382	Samples recovered from an old denuded hydrothermal mound area, represent relicts of fluid channelways, anhydrite custs, mud, sulfidic sinter, and siliceous sinter. All are presumed (inferred) to have been formed near to the original seafloor surface that underlay the mound, now largely dissolved away. It may be possible to date residual crusts radigenically.		
	PO 382-1	An irregular slab of residual anhydrite (now partly gypsum) surface crust. Its appearance suggests it was the root to a chimney or upflow conduit, being concave upwards with a vertical channel feeding out of it (ca. 8cm across). The underlying cavity is composed partly of altered indurated mudstone and sinter-like silica layers and seems to have been part of a lateral fluid channel.	40x20x10cm, ca. 6kg	large pieces to GPI Uni Kiel and TUBAF, slices to GSC and IceTec Iceland
	PO 382-2	This is a conforted siliceous finely layered sinter that now encloseds a red ockre, perhaps formerly a pyritic sulfide pod. It has interlayers of	25x20x10cm,	large pieces to GPI Uni Kiel and TUBAF,

		residual anhydrite. It is quite porous and has a sandy texture. Finely bedded laminae are conforted and imply slumping or differential compaction due to original mix of silica, sulfate, sulfide, mud, etc. The red portions are also largely siliceous, but still soft and friable.		slices to GSC and IceTec Iceland
	PO 382-3	Classical example of a hot spring anhydrite (now gypsum) breccia sinter where fragments are cemented strongly by 0.5 to 1.0mm black quartz (?) veinlets forming a tight network. A central zone of sulfate fragments remains soft, but above and below more massive layers are silicified and look weakly recrystallized.	25x20x8cm, 2.5kg	sliceces to GPI Uni Kiel, TUBAF, and GSC
	PO 382-4	2 pieces of reddish hematitic very soft brick-like material bearing <1% disseminate basalt glass grains. Looks to be an indurated mud from which silica has been removed and replaced by iron hydrolysates. Reminiscent of hydrothermal vent ochres, but not yet (re)silicified.	ca. 500g	pieces to GPI Uni Kiel, TUBAF, and GSC
	PO 382-5	Brown mudbrick of surface bioturbated material. Perhaps a residue of hydrothermal baked sediment from within the former mound.		pieces to GPI Uni Kiel and TUBAF
	PO 382-6	Small anhydrite-sulfide chimneys, broken up. Active coated with bacteria matter and their pyrolyzed remains. Iron sulfides?	12x5x5cm	pieces to GPI Uni Kiel and TUBAF
386	PO 386-1	2 pieces from a large active chimney cored by thick cauliflower textured white talc up to 4cm thick. Essentially botryoidal in habit, interior surface. Exterior is a thin coating of anhydrite crystals and minor pyrite grains plus bacterial pyrolyzates.	25x20x8cm, 2kg each	large piece to GPI Uni Kiel for display, small piece broken and divided to GSC, TUBAF, and JAGO
	PO 386-2	Chimney top with multiple spigots coated in black bacterial matte and coloured inside by talc, but only at its base. Top spigots are barely stained yellow. (Marker I and III, 1999)		chimney to TUBAF, bits to GSC

Core Description 337

0 - 20cm	brown green mud and fine anhydrite sand - main matrix < 1mm, interspersed with gravel to cobble size anhydrite lumps (up to 5 cm), a few are blackened (pyrite?) unconsolidated, thixotropic chaotic debris flow, unsorted, no bedding or structure
21 - 30cm 25cm	green brown mud (20%), anhydrite clots are fewer and up to 4 cm - roughly spheroidal (transition brown -> green) green-brown mud: unconsolidated, thixotropic, chaotic
30 - 46cm	green-brown mud, thixotropic, >= 20 - 30% fine anhydrite sand, few larger (cm) fragments
46 - 48cm	20% mud + 80% gravel size layer of anhydrite fragments browner than covering mud
48 - 65cm	30% mud, 70% coarse sand (mm -> 0.5 cm), rarer larger anhydrite grains to 2 cm
65 - 67cm	irregular anhydrite sand layer, 20% brown-green mud + 80% sand (0.2mm -> 4mm)
67 - 71cm	muddier 40% + 60% coarser cm-sized anhydrite
71 - 73cm	irregular band of grit anhydrite (brown patches) mm -> 1 cm, up to 80% clasts, rare black anhydrite (0.5cm), 20% green mud
73 - 78cm	patch of brown sand, amongst sandier muddy layer (20%) chaotic distribution of >= cm pieces
78 - 115cm	chaotic mixture of fine sand (60%), coarse lumps (15%), and brown-green mud (20%), debris flow chaotic mixture of sand, gravel, and mud in debris flow. Incr. browner green downwards
ca. 115cm	irregular scoured contac between sand/gravel debris flow and underlying brown-green mud (altered), structure of top indicates that underlying semi-indurated brown -> green mud was already altered and veined before scouring, hardest vein(s) is best preserved
120 - 127cm	isolated patches of sandier mud, anhydrite grains (1 - 3mm) are brown
127 - 152cm	„vein“ and alteration are about 4.5cm wide (150cm downwards), and 2.5cm wide (113cm downwards), but width of central vein broadens upwards over same interval, i.e. 0.2cm -> 0.5cm, „vein“ is a bleached grey and flanked by green to black (sulfide?) alteration, alteration is harder than vein, whose hardness = outer brownish mud: perhaps is a mud filled strinkage crack (previously altered?)

152 - 180cm veins becomes broader, more complex, and definitely harder,
boundaries with alteration are sharper and „vein“ appears to be bifurcating into a dual layer downwards

162cm distinctive parting surface(s)

180 - 186cm limit of disseminated pyrite (?),
vein begins above a scoured sandy layer (basaltic) intermixed with plastic blue-grey fine boulder clay (?) - mud clasts,
visible pyrite

186 - 210cm crudely interlaminated basaltic sand (hyaloclastitic) and blue-grey clay mud clasts (flattered and rounded), turbidite - proximal?
visible pyrite in hyaloclastite-rich zones,
increasing basalt glass (mm) downwards (30% -> 50%), less clay,
clay is blue-grey and grey-green, the paler material may be an alteration where fluid uses hyaloclastite „beds“ as channels,
minor patches of brown organic gel (gyttja?) in this interval,
increasing basalt glass (>50%) downwards, crudely laminated basalt glass and clay

210 - 216cm large clos of grey-green clay that are held by hyaloclastite matrix, note blue-grey alteration on margins of clots, pyrite

216 - 218cm a bed of glass (+ pyrite), (that connects to open space fill)

218 - 234cm cf 186 - 210
a more clay-rich mix of green-grey to blue-grey (alteration?) 60% : 40% ? + brown soft organics,
more chaotically mixed - turbidite of mud balls and hyaloclastite - represents a single bed?
0.5cm patches of brown organic (?) gel (gyttja),
mottled alteration troughout

234 - 235cm distinctive blue-grey clay (alteration?) layer

235 - 236.5cm hyaloclastite (+pyrite) layer

236.5 - 239cm distinctive blue-grey clay (alteration?)

239 - 244cm green-grey fine clay layer, <5% glass grains, scattered brown gel patches

244 - 247cm looks coarser, more (40%) glass-rich (+pyrite 1%)

EOH (260cm)

Core Description 339

The section is similar to 337 but less complex

0 - 64cm	consists of olive-green to green-brown gelatinous, homogeneous, thixotropic, pelagic, organic ooze. It is homogeneous and represents the least altered (protolith!) to dehydrated and altered mud lower down. Detailed chemistry is required (icl. LOI).
64 - 69cm	The base of the ooze bed has been dehydrated and has become a massive impermeable mud. It is brown in colour but remains of plastic consistency (cream cheese). It overlies an irregular layer of cobble-sized lumps of grey-white anhydrite (ca. 2 to 6cm), subrounded and closely packed with sub-cm chips. It may be a massive layer broken by coring or was a breccia.
69 - 75cm	It marks a gradation from anhydrite pieces mixed with brown-green mud downwards into a softer mud, patches of dehydrated ooze, and anhydrite chips.
75 - 83.5cm	It marks a bed of unsorted mm to cm-sized anhydrite grains, 3cm coobles, and hardened dark green-brown mud, thought to be altered. There are few pieces of grey-white anhydrite in the lower partof this layer.
83.5 - 90cm	This layer is a patchy mixture of anhydrite sand and gravel with loosely unconsolidated green-brown mud (formerly ooze), that is relatively unaltered cf. above. The section from 69 to 90cm is interpreted to be a hydrothermal aquifer where fluids utilize increased permeability of this heterogeneous sediment.
90 - 94cm	Interval marks a zone of virtually unaffected (not altered) but dehydrated organic mud well mixed with anhydrite sand grains. It contains preserved patches of gelatinous green-brown ooze.
94 - 105cm	This is a complex, patchy and blotchy altered interval that suggess limited passage of warm fluids down-welling along zones that are greyer than green to dark brown enclosing muds. This down-welling peters out at 105cm, and homogeneous mud prevails below.
105 - 117cm	Homogeneous, semi-indurated (plastic) green-brown mud.
117 -121cm	It marks the oxidized (bioturbated?) top to an underlying mud bed. Patches of yellow (ferric) colouration charaterize the top layer.
121 - 132cm	Homogeneous green-black mud with minor disseminated pyrite. Some dehydration is appearent, but mud is still plastic.

132 - 134cm	Diffusely bounded blue-grey alteration band within the mud sequence. It may mark the upper limits of the next lowerr hydrothermal aquifer.
134 - 144cm	Green-black mud is definitely much drier than above 130cm and contains disseminated pyrite.
144 - 150cm	Blacker patches within green-black mud testify to hydrothermal influences.
150 - 156cm	The core catcher stopped in drier, hard, non-plastic green-black pyritic mud. This implies a hydrothermal aquifer was just below.

EOH

Conclusions

Hot fluids percolating laterally away from upflow zones (vents) follow the most permeable horizonts within mud-sand sequences. These are usually characterized by the coarsest anhydrite gravel layer. Hot fluids dehydrate and crack adjacent impermeable muds and precipitate pyrite in so created pore spaces.

Conclusions

The hydrothermal upflow on the margins of the anhydrite mound permeated hyaloclastitic clay turbidites of probable proximal origin (no sorting etc.) until barred by a thick clay layer. However, this was dehydrated by high heat flow and produced shrinkage cracks which permitted further rise of ponded hot fluids. It reach the seafloor, only to be buried by local debris flows of organic (pelagic) mud and anhydrite fragments from nearby chimneys.
This core is considered to have penetrated the margins of the main upflow zone that fed the chimneys, and is affected by lateral outflow from it.

Core Description 347

This is a long section dominated by anhydrite debris flows and poorly developed proximal turbidite profiles. Clearly, these are formed in depressions on the side of slopes of hydrothermal mounds or ridges. The section can be subdivided into 3 or 4 discrete debris flows. Each shows evidence for coarse to finer upward deposition; typical of proximal turbidite debris flows.

Flow 1: 11 - 28cm (close proximal)
Flow 2: 28 - 90cm (close proximal)
Flow 3: 90 - 120cm (close proximal)
Flow 4: 120 - 177cm (more distal, but proximal)
Flow 5: 177 - 219cm (more distal)

0 - 11cm — is a typical seafloor brown-green oxidized organic ooze, thixotropic and gelatinous pelagic matter. Its base includes loose anhydrite gravels.

11 - 20cm — Uppermost anhydrite consists of an unsorted sand to gravel sized pack of iron-stained (in patches) grains that become progressively paler downwards.

20 - 28cm — This interval consists of gravel to cobble sized (to 6cm) chunks of grey anhydrite marking the base of this flow.

28 - 88cm — is a thick section of relatively homogeneous sand-sized (mm - cm) anhydrite debris.

88 - 90cm — Its base is a thin bed of coarser pale orange-brown grains. These coarse zones appears to behave as fluid pathways, hence staining.

90 - 118cm — marks the top of a thick section of grey to buff white homogeneous sand (mm - cm). It coarsens downwards.

118 - 120cm — is the base of this debris flow and consists of pale orange-brown gravelly anhydrite (0.5cm -> 2cm)

120 - 177cm — The entire sequence consists of largely coarse sand to gravel sized anhydrite grains distributed into alternating bands of coarse orange-brown and sandy buff white anhydrite. Overall, this entire sequence coarsens downward reaching cobble plus gravel at 177cm.

120 - 127cm	buff white sand -> gravel
127 - 133cm	pale orange-brown gravel
133 - 138cm	buff white sand -> gravel
138 - 140cm	pale orange-brown gravel
140 - 152cm	buff white sand to gravel
152 - 160cm	coarser gravel layer (mm - 2cm) + cobbles
160 - 174cm	buff grey gravel to cobble + 30% sand

174 - 177cm	yellow to orange-brown stained cobble dominated gravel
177 - 219cm	This sequence is characterized by numerous thin bedded alternating sand to gravel turbidites. All bands are diffusely defined, interval contains the following sequences:
177 - 182cm	grey sand
182 - 184cm	white sand to silt
184 - 187cm	grey sand
187 - 189cm	white sand to silt
189 - 193cm	grey sand
193 - 195cm	white sand to silt
195 - 197cm	grey sand
197 - 200cm	white sand to gravel
200 - 203cm	grey sand to gravel: yellow stain
203 - 206cm	white sand: stained
206 - 209cm	grey sand to gravel
209 - 210cm	a thin grey-black hard pan of anhydrite ± quartz? This may marl an old seafloor surface or a warm fluid pathway.
210 - 214cm	white silt to sand: much yellow stain
214 - 216cm	white silt to sand
216 - 217cm	grey sand
217 - 218cm	white sand
219 - 219.5cm	thin layer of black hard pan
219.5 - 222cm	more lense-like mm thick hard pan in sand (old seafloor?)
222 - 225cm	grey buff sand
225 - 226cm	black lensoidal to discoidal hard pan
225 - 228cm	grey buff sand
228 - 229cm	white sand
229cm	mm thick ferric oxide wave band
230 - 236cm	indistinct zone of interbedded buff andwhite sandy layers
236 - 238cm	white sand and weak iron stains at base
238 - 247cm	buff brown sained sand to gravel layer
247 - 262cm	buff brown iron-sained gravelly layer
262 - EOH	mix of gravel and coarser cm to 3cm cobbles at end of hole.
EOH	

<u>Conclusions</u>

It is clear from the presence and intensity of iron staining that passage of lateral fluids favours the coarsest parts of these turbidite/debris flow sequences. The fact that ferric iron staining is dominant rather than reducing sulfidic additions suggests that these units may be zones of recharge of oxygenated seawater rather than of discharge of H2S-rich fluids. Perhaps the underlying mud sequences (not reached) provide a barrier to upwelling hot fluids that are confined to deeper zones.

Core Description 370

This was a boiling core that severely disrupted the central portions of the section by steam cavitation.

0 - 16cm	The overlying pelagic mud is more dehydrated nearer surface than seen previously. Only the top few cm retain typical thixotropic gel-like consistency, olive-green colour. (Viggo sample #1 at 16cm)
16 -36cm	Similar dark olive-green soft mud mottled with faint pale brown speeks suggestive of bioturbation (implication: an old sediment, not a turbidite), not seen elsewhere.
36 - 65cm	Olive-green mud grades into paler grey-green semiplastic mud (less hydrous), faintly mottled with small darker (sub-cm) patches. It becomes progessively harder and drier down to about 65cm. (Viggo sample #2 at 65cm)
65 - 100cm	A less homogeneous grey plastic mud, mottling is therefore little darker. Some softer patches are apparent. Over this section the mud appears to soften downwards. (Viggo sample #3 at 90cm)
100 - 117cm	Temperature ca. 90°C, when recovered. Mud is now semi-indurated (crumbley), pale grey with darker mottling (a mudstone was found). It is weakly pyrite as disseminations and discontinous veinlets (□0.1mm).
117 - 140cm	Crumbly mudstone as above broke up during recovery due to boiling and cavitation in the tube (ca. 60cm). Section is restored. Disseminated pyrite troughout.
140 - 170cm	Further cavitation and crumbling of mottled grey pyritic mudstone. Texture and consistency remain homogeneous.
170 - 215cm	Sharp reversion to very soft plastic pale grey mud, thixotropic well mixed with no mottling. May have been rehydrated during recovery - clearly partof an aquifer system; contains sparse disseminated pyrite. Grey colour is typical of high-temperature alteration.
215 - 240cm	An angular breccia of soft grey mud (10 to 15%) and pyritic recrystallized anhydrite in blocky chunks up to 5cm thick. This may have been an intact plate until disrupted by the corer and subsequent boiling and mixing. Pyrite lies along crystal plate boundaries as platy sheets, 0.1mm thick. Should be useful for boiling fluid iclusion work and □^{34}S on equilibrium anhydrite/pyrite pairs. Hole ends at 240cm in coarse „breccia“, mainly gravel size in the core catcher.

EOH

Core Description 372

This is an unusually complex section both mineralogically and in terms of the degree of intense Mg-metasomatism the claystones have undergone.

0 - 110cm	Normal olive-green hemipelagic thixotropic, homogeneous mud, but with variations due to steep geothermal gradients encountered downhole.
0 - 20cm	soft, gelatinous mud
10cm	location of Viggo sample #1
20 - 40cm	partly dehydrated to a semiplastic consistency, still thixotropic, olive-green to green-brown transitional colours
30cm	location of Viggo sample #2
40 -77cm	green-brown hardend mud, no longer plastic but friable to crumbly, strongly dehydrated (Analyses of these mud samples 0 - 110cm should include water loss at 120°C and LOI at 800°C)
60cm	location of Viggo sample #3
77 - 90cm	dark green-brown hardened crumbly mudstone
88cm	location of Viggo sample #4
90 - 105cm	strongly dehydrated mudstone, noe mid-brown in colour
105 - 110cm	hard brick-like, brown mudstone that contains metasomatic minerals such as a soft brown prototalc (?), sub-mm to 0.5cm in size, about 7%, and sub-mm to 0.1mm grains of disseminated pyrite
110 - 130cm	Distinctive blue-grey altered mudstone, but softer than above. It contains mottled patches of brown to orange-brown soft to gelatinous flaky minerals, thought to be talc or an alteration of talc. Unit is 10% brown, 90% blue-grey. This unit marks the top of a hydrothermal aquifer that has metasomatized a section of pelagic mud and baked the rest.
130 - 150cm	Sediments as above but proportions are now 50% each of brown gel and blue-grey altered claystone with disseminated pyrite troughout both phases. Texture is irregularly blotchy (cm-size).
136cm	location of Viggo sample #5
150 - 166cm	Sediments as above, but now 80% blue-grey claystone and 20% soft brown gelatinous patches plus a few paler brown botryoidal (2cm) clots of recognizable talc. The section is semi-dehydrated (or perhaps rehydrated) and contains sparse disseminated pyrite.
166 - 186cm	From here downwards exists a set of horizontally diffusely striped bands of soft near gelatinous pale brown talc-like mineral that may be prototalc or an altered talc, alternate with darker brown gelatinous talc-like minerals. All colours are mottled with those of each band plus a little blue clay.

186 - 230cm Weakly interbanded pale brown very soft granular talc and blue-grey drier clay become progressively dehydrated (or less altered?) downwards. Sparse disseminated pyrite.

200 - 230cm Blue-grey beds alternate with pale brown beds - generally twice as much of the former. Granularity becomes more distinctive and is typically coarse sand-sized (sub-cm). Section is more dehydrated and harder downwards.

230 - 260cm Marks the top of a sequence of very poorly defined equally thin interbeds of alternating blotchy blue-grey > pale brown and blotchy pale brown > blue-grey. I.e., higher proportion of intermixing and each bed about 2 to 3 cm thick.

240cm location of Viggo sample #6

260 - 300cm Fiffuse banding is largely obliterated to form spotty to blotchy intermixtures of talc and clay.
The core catcher yielded 80% talc, 20% clay, and a little fine pyrite.

EOH

Conclusions

In summary, a well defined hydrothermal aquifer has been defined that has partly altered a covering pelagic mud section. The origins of the weakly banded units and the contained talc-like minerals are contentious.
It is possible that intense Mg metasomatism has altered pelagic mud to such an extent as to synthesise talc or its precursors. This is likely the case in the section from 110 to 130cm.
Fluids carrying Mg and Si may have been derived from within the aquifer itself or from a nearby upflow zone. The core may be sited on the flanks of an active mound or ridge.
Alternatively, experience from thick anhydrite debris flows that constituded section of GC-347 where well-laminated talcose anhydrite turbidites were described, supports an alternative mechanism for generating clay-talc interlamnations here.
If all anhydrite were dissolved, only talc and clay would remain. High-temperature lateral fluid flow may remobilize Mg and Si altering talc to gelatinous residues and promote metasomatism of containing upper muds.
In this scenario, the most intensively altered section would therefore be from 110 to 130cm for a zone of Mg and Si addition. The zone of Mg and Si depletion would be from about 130 to 230cm. Original talc-clay ± anhydrite would be best preserved below this level.
Investigation of the chemistry of talc, talc-like gels and grains, clays, as well as □^{18}O work on each may help resolve these questions. Degree of crystallinity versus amorphous character may also be helpful.

Core Description 374

This represents a long (3m) section of hemipelagic mud and imposed hydrothermal alteration on that material.

0 - 110cm	Hemipelagic mud, olive-green to green-brown downwards, thixotropic to semiplastic, increasingly dehydrated downhole to 110cm where texture and consistency charges to semidry, friable, and crumbly.
0 - 18cm	gelatinous ooze, no preserved oxidized top, reducing + smell of H_2S
20cm	location of Viggo sample #1
18 - 110cm	mud changes colour gradually and becomes increasingly dehydrated
40cm	location of Viggo sample #2, thixotropic, green mud
63cm	location of Viggo sample #3, thixotropic, green mud
90cm	location of Viggo sample #4, thixotropic, green mud
100cm	diagenetic pyrite
110 - 166cm	Now semiplastic green-brown unaltered mud increasingly dry downhole. A series of pyrite samples (euhedral crystals, thin plates, wires) were panned at regular intervals from herre down. Useful for $\square^{34}S$ variation, textural changes, gold and trace chemistry.
114cm	location of Viggo sample #5, smell of H_2S
159cm	location of Viggo sample #6, smell of H_2S
166 - 193cm	At 166cm mud is green-brown, semiplastic and shows signs of alteration. This is the uppermost expression of visible altered hemipelagic mud, in the form of a vein of pale brown alteration thatis flanked by darker green-brown „wallrock“. Vein mud is softer than surrounds indicating a fluid passageway stoping upwards. These and other „veins“ should be sampled and analyzed separately from „wallrocks“.
193cm	location of Viggo sample #7
200cm	this weal alteration vein peters out into dark green mud
193 - 239cm	Mud is now darker olive-green, dehydrated and crumbly, semiplastic.
230cm	mud is no longer plastic but friable and crumbly
239cm	appears to be the limit of development of diffuse, streaky pyrite veinlets amongst increased quantities of disseminated grains
239 - 261cm	Considerable (ca. 2% in places) disseminated- mainly wire - pyrite in crumbly dark green midrock. This interval is likely the hot zone (down o 290cm) in the section.

261 - 280cm Similar pyrite distribution but mudrock is now distinctively altered to blue-grey colours and is softened by the presence of blotchy, brown gels. The sediment is weakly banded and colours are intermixed.

280 - 284cm End of the dry zone in a distinctive blue-grey altered clay band.

284 - 290cm Mid-brown gelatinous material that is either prototalc or a talc hydrolyzate (sample separated for analyzing).

290 - 300cm Several brown and blue-grey bands somewhat intermixed. Material is coarser and harder in the core catcher and carries pyrite.

EOH

Conclusions

The unusual nature of alteration (metasomatic) soft veins indicates a mechanism operative that reveals the process by which upwelling or laterally moving hydrothemal fluids can eventually reach the seafloor. High heat flow in a geothermal aquifer serves to dehydrate, bake and ultimately shrink the overlying hemipelagic mud (ca. 30% water) to permit hot water to rise into microfractures and sediment pores, created by dehydrating clays and organic gels. Further alteration to hydrous clays causes colour changes and presumably chemical changes (Mg metasomatism?) as these „veinlets“ of alteration stope upwards. Since these may be numerous and anastomosing, their coalescence can create a chimney-like conduit towards the surface into which sulfides can precipitate (cf. Middle Valley). The end result will be meandering veins that can ultimately form a pipe-like body of sulfides or more likely, an array of veins that may vent (VMS) or die out below the seafloor (epithermal).
This model is further supported and enhanced by the remarkable „vein“ sequence encountered on GC 369.

Station no.	Sample no.	Sample description	$-O_2$ 4°C	$+O_2$ °4C	In situ –20°C	-20°C
323	J0101	Piece of anhydrite	+	+		
323	J0102	Chimney (250°C)	+	+		
328	J0201	Water from Niskin bottle 500 ml	+		+	+
328	J0202	Core 2 cm				+
328	J0203	White filaments	+	+	+	+
337	K-0101	Core anhydrite 7 cm	+			
337	K-0102	Core anhydrite 9 cm	+			
337	K-0103	Core anhydrite 20 cm	+			
339	K-339	Core samples 104 and 132 cm 15/7	+	+		
353	K-353	Core topp 30 cm 100 ml 15/7		+		
353	K-353	Core base 5 m 100 ml 15/7				
367	J04 trap sed	Sediment under bacterial trap 50 and 100 ml	+		+	
367	J04 trap con	Trap filltratio3x membrane	+	+	+	+
367	J04 trap gel	Solid scrapings			+	+
369	K-369 A	Core 10 cm 20/7	+			+
369	K-369 B	Core 20 cm 20/7	+			+
369	K-369 C	Core 30 cm 20/7	+			+
370	K-370 A	Core 16 cm 19	+		+	
370	K-370 B	Core 60 cm	+		+	
370	K-370 C	Core 1690 cm	+		+	
372	K-372 A	Core 8.5 cm 19/7 special	+		+	
372	K-372 B	Core 34 cm 19/7 special	+		+	
372	K-372 C	Core 62 cm 19/7 special	+		+	
372	K-372 D	Core 88 cm 19/7 special	+		+	
372	K-372 E	Core 136 cm 19/7 special	+		+	
372	K-372 F	Core 2004cm 19/7 special	+		+	
374	K-374 A	Core 20 cm 20/7 since 18/7	+			+
374	K-374 B	Core 40 cm 20/7 since 18/7	+			+
374	K-374 C	Core 63 cm 20/7 since 18/7	+			+
374	K-374 D	Core 90 cm 20/7 since 18/7	+			+
374	K-374 E	Core 113 cm 20/7 since 18/7	+			+
374	K-374 F	Core 158 cm 20/7 since 18/7	+			+
374	K-374 G	Core 194 cm 20/7 since 18/7	+			+
380	J05	PO 380:2 chimney mix	+		+	
381	K-381	Core catch 75°C hot 19/7	+	+	+	+
382	J06	Chimney interieur	+		+	
382	J06	Chimney exterieur	+		+	
382	J06	Chimney mix		+		
386	J07 CH-int	Chimney (anhydrite)PO386 pure yellow/white stuff scraping pict	+		+	+
386	J07CH-ext	Chimney (anhydrite)PO386 mixed black/white stuff scraping pict	+		+	+
386	J07CH-ext2	Chimney (anhydrite)PO386 pure white stuff, layer under ext scraping pict	+		+	+
386	J07 trap 9	Concetrate bacterial trap 9	+	+	+	+
386	J07 trap 8	Cocentrate bacterial trap 8	+	+	+	+

J= Dive JAGO
K= Core samples

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Station no.	Sample no.	Sample description	$-O_2$ 4°C	$+O_2$ °4C	In situ –20°C	-20°C
	K-374 A	Core 20 cm 20/7 since 18/7	+			+
	K-374 B	Core 40 cm 20/7 since 18/7	+			+
	K-374 C	Core 63 cm 20/7 since 18/7	+			+
	K-374 D	Core 90 cm 20/7 since 18/7	+			+
	K-374 E	Core 113 cm 20/7 since 18/7	+			+
	K-374 F	Core 158 cm 20/7 since 18/7	+			+
	K-374 G	Core 194 cm 20/7 since 18/7	+			+
	K-381	Core catch 75°C hot 19/7	+	+	+	+
	K-372 A	Core 8.5 cm 19/7 special	+		+	
	K-372 B	Core 34 cm 19/7 special	+		+	
	K-372 C	Core 62 cm 19/7 special	+		+	
	K-372 D	Core 88 cm 19/7 special	+		+	
	K-372 E	Core 136 cm 19/7 special	+		+	
	K-372 F	Core 2004cm 19/7 special	+		+	
	K-370 A	Core 16 cm 19	+		+	
	K-370 B	Core 60 cm	+		+	
	K-370 C	Core 1690 cm	+		+	
	J05	PO 380:2 chimney mix	+		+	
	J06	Chimney interieur	+		+	
	J06	Chimney exterieur	+		+	
	J06	Chimney mix		+		
	K-339	Core samples 104 and 132 cm 15/7	+	+		
	K-352 ?	Core topp 30 cm 100 ml 15/7		+		
	K-352 ?	Core base 5 m 100 ml 15/7				
	J04 trap sed	Sediment under bacterial trap 50 and 100 ml	+		+	
	J04 trap con	Trap filltratio3x membrane	+	+	+	+
	J04 trap gel	Solid scrapings			+	+
	J07 CH-int	Chimney (anhydrite)PO386 pure yellow/white stuff scraping pict	+		+	+
	J07CH-ext	Chimney (anhydrite)PO386 mixed black/white stuff scraping pict	+		+	+
	J07CH-ext2	Chimney (anhydrite)PO386 pure white stuff, layer under ext scraping pict	+		+	+
	K-369 A	Core 10 cm 20/7	+			+
	K-369 B	Core 20 cm 20/7	+			+
	K-369 C	Core 30 cm 20/7	+			+
	J07 trap 9	Concetrate bacterial trap 9	+	+	+	+
	J07 trap 8	Cocentrate bacterial trap 8	+	+	+	+
	J0101	Piece of anhydrite	+	+		
	J0102	Chimney (250°C)	+	+		
	J0201	Water from Niskin bottle 500 ml	+		+	+
	J0202	Core 2 cm				+
	J0203	White filaments	+	+	+	+
	K-0101	Core anhydrite 7 cm	+			
	K-0102	Core anhydrite 9 cm	+			
	K-0103	Core anhydrite 20 cm	+			

J= Dive JAGO
K= Core samples

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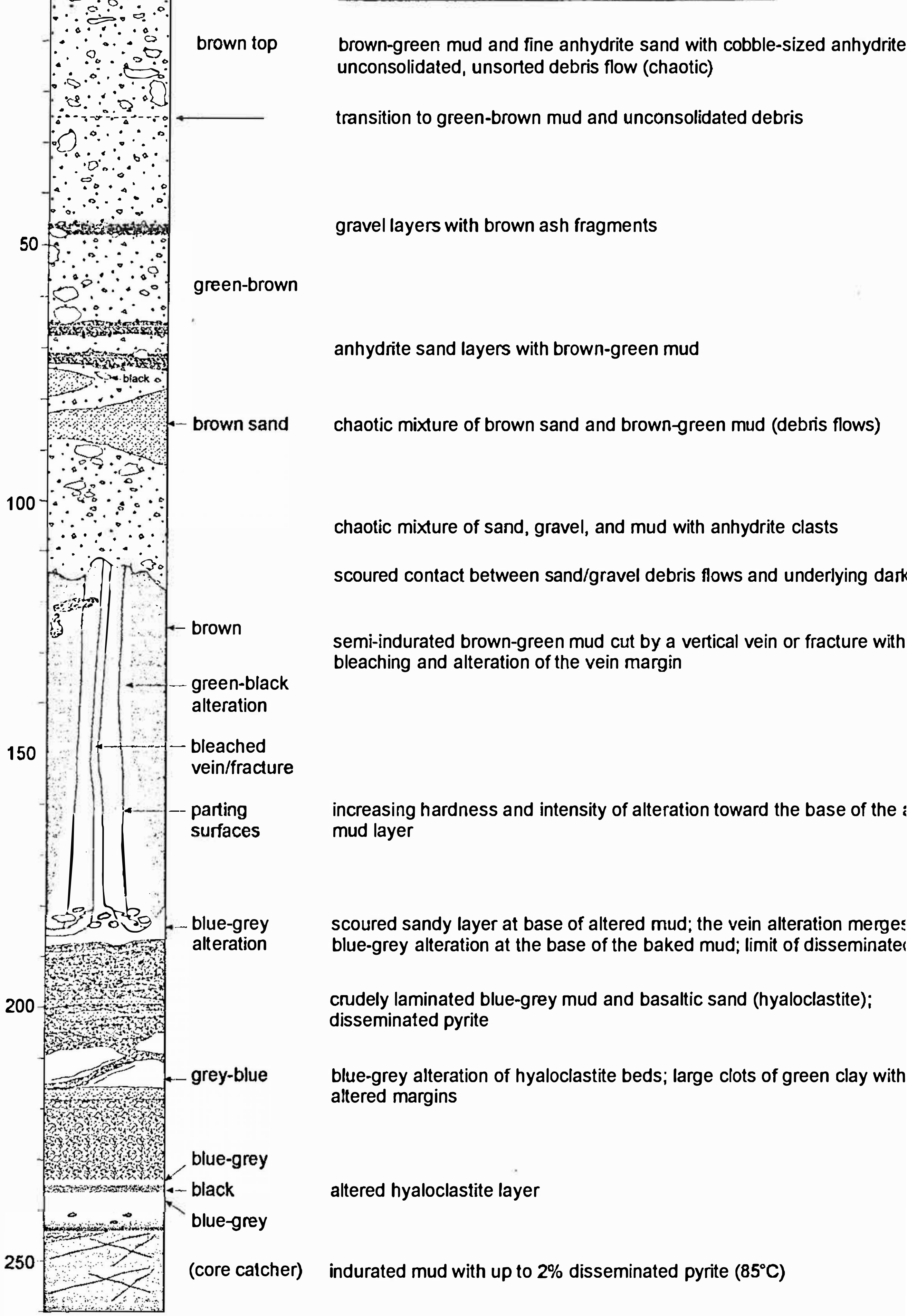
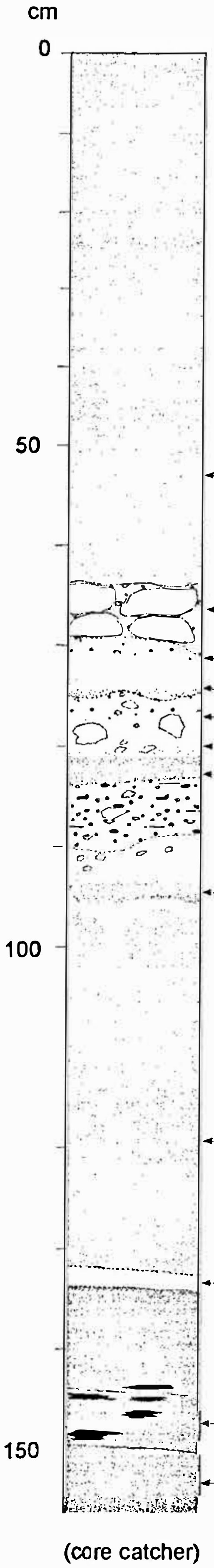
Station no.	Sample no.	Sample description	$-O_2$ 4°C	$+O_2$ °4C	In situ –20°C	-20°C
	K-374 A	Core 20 cm 20/7 since 18/7	+			+
	K-374 B	Core 40 cm 20/7 since 18/7	+			+
	K-374 C	Core 63 cm 20/7 since 18/7	+			+
	K-374 D	Core 90 cm 20/7 since 18/7	+			+
	K-374 E	Core 113 cm 20/7 since 18/7	+			+
	K-374 F	Core 158 cm 20/7 since 18/7	+			+
	K-374 G	Core 194 cm 20/7 since 18/7	+			+
	K-381	Core catch 75°C hot 19/7	+	+	+	+
	K-372 A	Core 8.5 cm 19/7 special	+		+	
	K-372 B	Core 34 cm 19/7 special	+		+	
	K-372 C	Core 62 cm 19/7 special	+		+	
	K-372 D	Core 88 cm 19/7 special	+		+	
	K-372 E	Core 136 cm 19/7 special	+		+	
	K-372 F	Core 2004cm 19/7 special	+		+	
	K-370 A	Core 16 cm 19	+		+	
	K-370 B	Core 60 cm	+		+	
	K-370 C	Core 1690 cm	+		+	
	J05	PO 380:2 chimney mix	+		+	
	J06	Chimney interieur	+		+	
	J06	Chimney exterieur	+		+	
	J06	Chimney mix		+		
	K-339	Core samples 104 and 132 cm 15/7	+	+		
	K-352 ?	Core topp 30 cm 100 ml 15/7		+		
	K-352 ?	Core base 5 m 100 ml 15/7				
	J04 trap sed	Sediment under bacterial trap 50 and 100 ml	+		+	
	J04 trap con	Trap filltratio3x membrane	+	+	+	+
	J04 trap gel	Solid scrapings			+	+
	J07 CH-int	Chimney (anhydrite)PO386 pure yellow/white stuff scraping pict	+		+	+
	J07CH-ext	Chimney (anhydrite)PO386 mixed black/white stuff scraping pict	+		+	+
	J07CH-ext2	Chimney (anhydrite)PO386 pure white stuff, layer under ext scraping pict	+		+	+
	K-369 A	Core 10 cm 20/7	+			+
	K-369 B	Core 20 cm 20/7	+			+
	K-369 C	Core 30 cm 20/7	+			+
	J07 trap 9	Concctrate bacterial trap 9	+	+	+	+
	J07 trap 8	Cocentrate bacterial trap 8	+	+	+	+

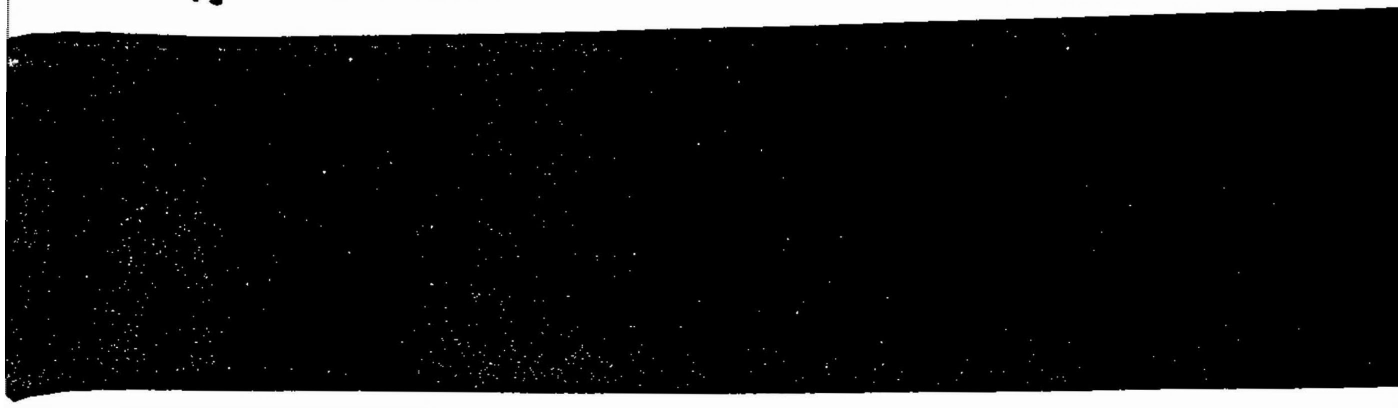
Summary Schematic Log (Core SL-337)



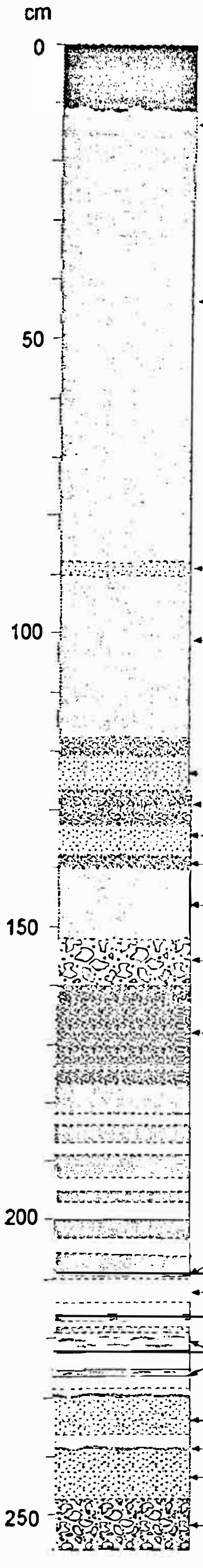
Summary Schematic Log (Core SL-339)



LRT-BE4-V3

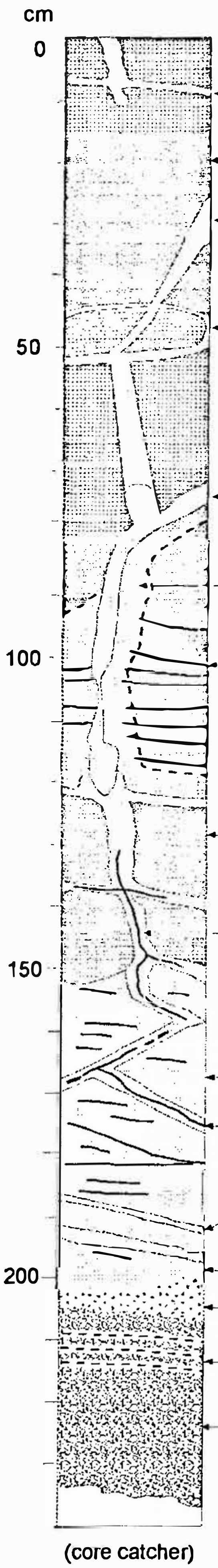


Summary Schematic Log (Core SL-347)



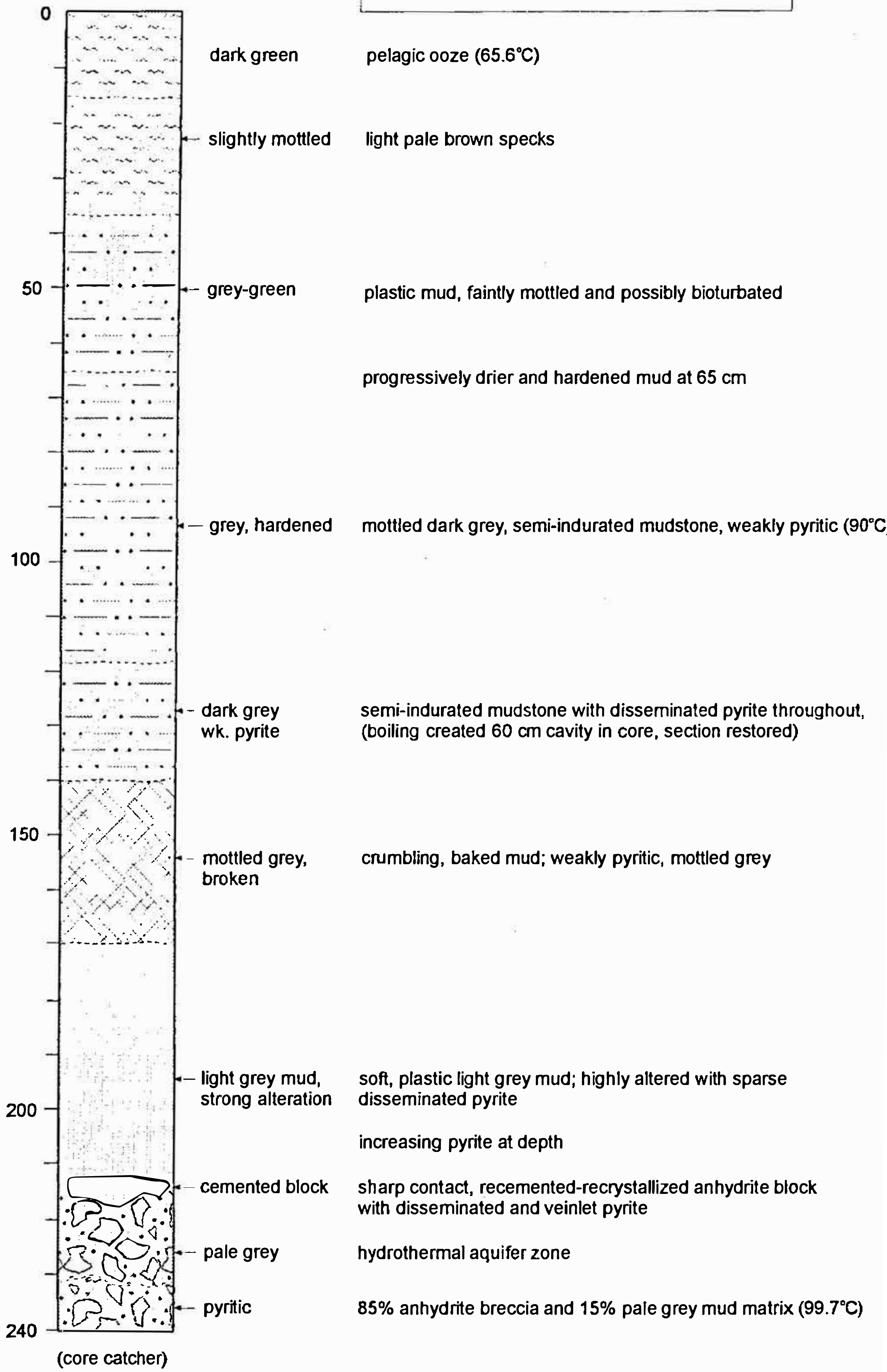
brown-green	pelagic ooze
brown patches Fe-stained	anhydrite gravel at top of anhydrite zone
grey-white	anhydrite sand with coarser anhydrite clasts (up to 5 cm)
	anhydrite (+talc) sand
pale pink	coarser gravel layer, possibly with abundant talc (top of next debris
buff, grey-white	anhydrite (+talc) sand
grey-white	alternating layers of loose, stained anhydrite sand and gravel
pale orange-brown	coarser orange-brown stained gravel layer
white	
pale orange-brown	
buff white	anhydrite (+talc) sand
pale orange-brown to grey-green	
buff grey	coarse anhydrite gravel layer (+talc), coarsening downwards (clasts up to 5 cm)
alternating grey and white	sandy debris flows (rhythmic banding?)
Fe-staining	coarser white sand and gravel with yellow stain (anhydrite+talc)
white, yellow stain	
dark patches	two layers of brecciated hardened debris (silicified?) with black len
Fe-staining	
buff and white	indistinct buff and white layers with locally strong Fe-oxide stain
Fe-staining	
buff brown	mixed sand and gravel, weakly Fe-stained
buff brown, Fe-staining	mixed sand and gravel, weakly Fe-stained, coarsening downward
(core catcher)	(20°C)

Summary Schematic Log (Core SL-369)

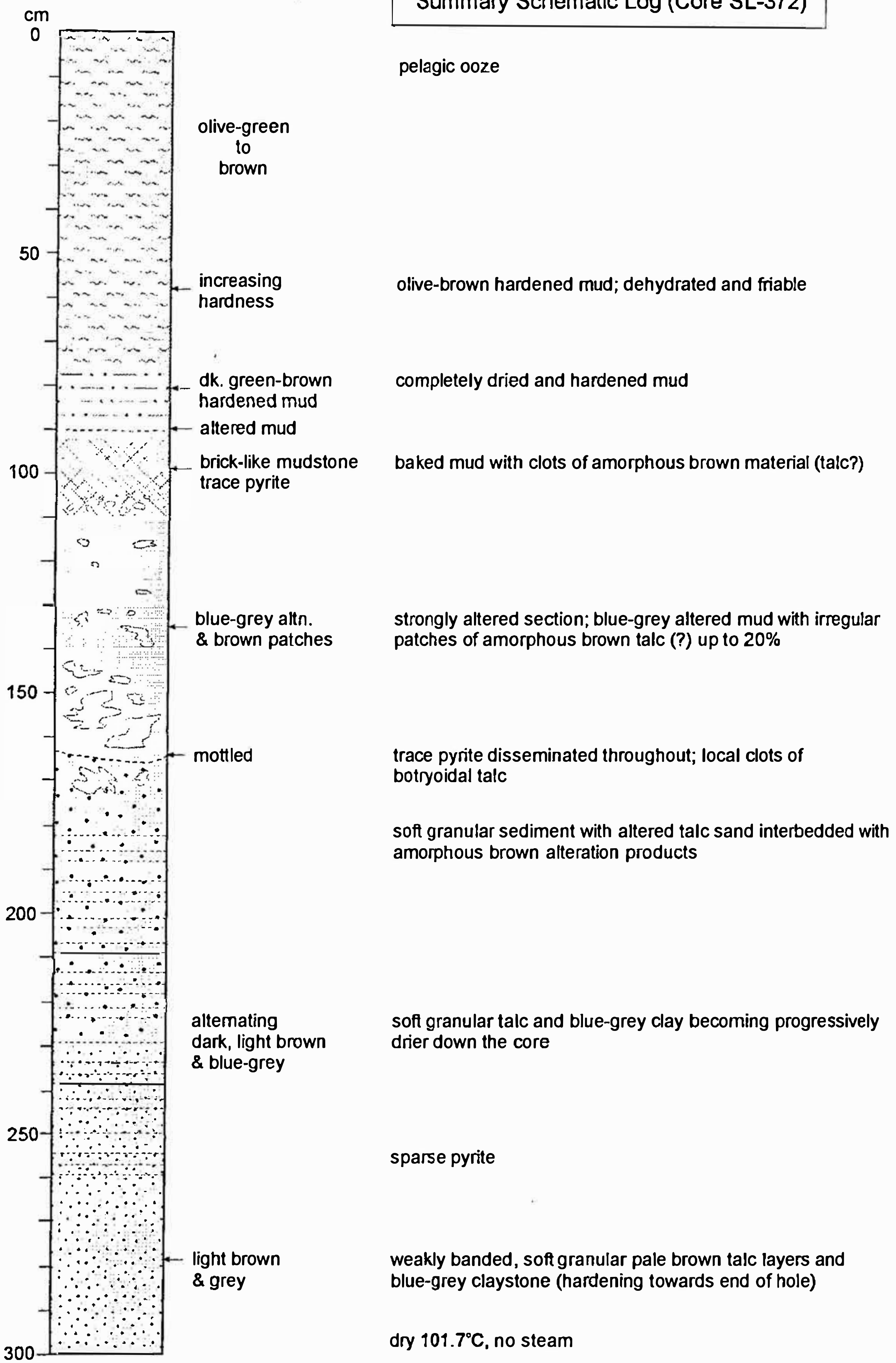


pale brown alteration	olive-green mud veined by softer pale brown mud (upflow); strongly dehydrated
olive green	(63°C)
pale brown alteration	
mud clot	disseminated pyrite and fracture-lining pyrite around mud clot
blue-grey alteration	cavitation and parting with abundant pyrite veinlets in transition between olive-green to brown mud
pale brown alteration	hot zone with well-developed alteration veins grading downward into blue-grey alteration; anastomosing veins
streaked mud	
brown mud	semi-indurated brown-green mud cut by notable bleaching and alteration
pyrite	increasing hardness and intensity of alteration toward the base of the altered mud layer
pale grey-brown	vein of pale brown alteration with discontinuous veinlet of pyrite at center (up to 1 mm); abundant pyrite veinlets on partings in drier mud
pyrite	
pale brown alteration	
blue-grey	
dk. brown alteration	brown amorphous material (altered talc?)
pyrite	
blue-grey	sandy talc grading downward into coarser gravel with recrystallized anhydrite, blue-grey clay, and disseminated pyrite
	(101.6°C)

Summary Schematic Log (Core SL-370)

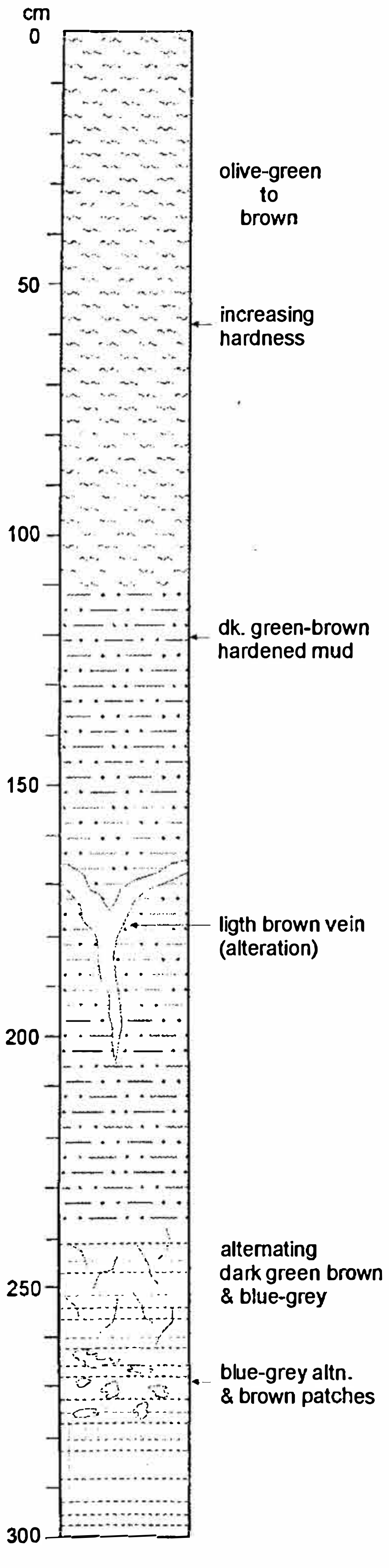


Summary Schematic Log (Core SL-372)



LRT-BE4.V3

Summary Schematic Log (Core SL-374)



pelagic ooze (16°C)

olive-brown mud; increasingly dehydrated and friable

increasingly dried and hardened mud

vein of light brown alteration (softer than surrounding baked mud); probable fluid pathway

limit of diffuse veinlets and dissemination of pyrite

baked mud with clots of amorphous brown material (talc?)

weakly banded, soft granular pale brown talc layers and blue-grey claystone (hardening towards end of hole)

99.1°C